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The Domain of Adaptive Systems:
A Rudimentary Taxonomy

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The Domain of Adaptive Systems: A Rudimentary Taxonomy

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ABSTRACT

Several divisions of contemporary inquiry—general systems analysis, cybernetics, the social and life sciences, and particularly the management sciences—are presently confronted with metascientific problems both conceptual and methodological in character. This situation is the result of a continuing drive toward comprehensiveness that has carried modern science beyond the limited scope of an earlier preoccupation with deterministic systems. However vaguely it may as yet have been conceived, a unifiable domain of adaptive systems appears to be emerging as the locus of a general convergence of the behavioral sciences on problems that generate a new order of theoretical difficulty. In this context a rudimentary taxonomy of adaptive systems is proposed as a means of structuring this area of research. Contrary to the usual supposition that the various behavioral sciences are concerned with quite disparate types of systems, this taxonomy presupposes a unitary format of organization and transformation derived on the basis of the concept of emergence. Rough measures of increasing systemic complexity are employed to order emergent systems within a total domain that is everywhere conformal with respect to the utilization of selective (or adaptive-control) processes for the attainment of viable organization and characteristic response. The resulting classification scheme—a unitary hierarchy incorporating (a) inorganic, (b) organic, and (c) conceptual systems—is, first of all, suggestive of further taxonomic refinement that will require the formulation of a continuous measure of systemic complexity. In a more significant development, however, this taxonomy leads to a conceptualization of a normative-theoretic approach to behavioral inquiry as a highly promising complement to the traditional objective-theoretic approach. If both projects—taxonomic refinement and theoretical reorientation—are carried forward in an iterative process, it is felt that a unitary format for general systems analysis can ensue as a fundamental rationale for the behavioral sciences.

INTRODUCTION

The considerations presented in this paper concern the problem of attaining a comprehensive structuring of the domain of research areas comprising behavioral* inquiry. The propriety of generating such a project initially from the perspective of the particular interests of management science might, of course, appear to be immediately questionable. In anticipating such an objection, we would maintain that management science—insofar as it is construed as a rational activity that purports to provide resources for improving the decisions of a client organization—must encounter the acute problems of its companion behavioral sciences with respect to the analysis of systems, as well as certain particularly difficult problems unique to its own special province.

As a justification of the approach being taken, we are concerned with pointing out the origins of our interest in a taxonomy of adaptive systems, first, with respect to the unique province of management science and, second, with respect to the broader area of behavioral inquiry in general.

Prospectus for Management Science

It is presumably the decision-oriented character of management science that accounts for impending difficulties peculiar to its specialized problems. At least three primary domains of decision necessarily confront any client: (1) action, (2) policy, and (3) organization. Any attempt to provide operations research with resources for resolution of problems in all these domains (some of which are obviously quite intractable in the present state of the profession) must accept the challenge inherent in an escalade of increasingly complex theoretical projects: (a) theory of decision, (b) theory of value, and (c) theory of selective systems, i.e., a theory of organization in general. Further, the attainment of adequate comprehension of decision-valuation-organization processes collectively as determinants to behavior, and particularly the establishment of criteria for "improved" decisions, will require methodological development in all these areas with their integration into a systematic structure. Such a line of investigation can therefore not be terminated short of a theory of the cognitive process *per se*.

*We must immediately disclaim any interpretation of "behavioral inquiry" that would identify our use of the term with the abortive attempt of the Chicago school of behaviorists (Watson, Hoisington, Dashiell, *et al.*, 1910–1930) to carry out a radical reduction of psychological phenomena on a rudimentary mechanistic basis. "Behavioral inquiry" is intended in general reference to the acceptance of a fundamental modification of the earliest directive of inquiry. Under this modification the question: How does this system characteristically interact with other systems comprising its environment? replaces the venerable but apparently abortive question: What *really* is the essential nature of this thing? When, in the context of either formal or experimental investigation, this emphasis on dynamic interaction is coupled with the notion of modifiable characteristic response via *internal* system controls, the result is behavioral inquiry.

Under a research prospectus very similar to that just ascribed to the management-science profession, we have recently been engaged in an attempt to develop one component of a theory of the cognitive process: a theory of cognitive controls associated not only with rationality but with evolutionary viability as well. These investigations[1] have necessitated a transformation of scientific method into a more general complementary-conformal method. Such a transformation is required for the incorporation of valuation (prescription) with knowledge (prediction) under rational control. Because of the conformal nature of the method the convergence of many specialized disciplines under a single methodological structure is indicated, and this intimation has become a focus of research activity.

An Iterative Process of Inquiry

As a consequence of this development, we have become involved in an iterative process of inquiry. Beginning with an intuitive notion of practical decision systems (the ordinary context of corporate decision making), it was immediately recognized that valuation, as a determinant to decision, necessarily entails a difficult methodological problem. If decision systems, with their concomitant value concerns, are to be placed at the center of interest in the domain of operations research, what mode of inquiry may be taken as appropriate and adequate for a rational treatment of the perennial difficulties that have characterized value judgment? It is this question, of course, that inevitably forces a rudimentary science of management into an unfamiliar region of metascientific issues and problems.

With the expectation that some modification of the presently accepted pattern of scientific inquiry would constitute a prerequisite to adequate rational control of value judgments, an examination of successive historic modifications of both scientific and axiological modes of inquiry was undertaken. The gratifying result[1] was the realization that (a) the "conceptual" mode of inquiry—developed during recent decades in the course of a revolution in modern physics—was open to reconstruction as a formal <u>dual</u> and (b) under exploitation of a resultant complementarity there emerged, in addition to the predictive format of scientific inquiry, a prescriptive format directly applicable to value inquiry. Thus the way appeared to be open for the establishment of a rational process for the control of valuation, and hence for the development of general theories of value and decision.

However, in subsequent attempts to work out the details of a rationale for prescription—a formal basis for the selection and institution of values and norms for a decision system as a <u>subject</u> or idiosystem*—two imposing obstructions were encountered. First, complications were injected by the realization that the cognitive process comprises not only the control process that was our initial concern, but also an aesthetic process and, even more important, a creative process—both of which entail considerations relevant to a

*A difficult problem in the selection of terminology is associated with the use of "idiosystem" as synonymous with "system-as-a-subject." The term "self-system," which would seem to apply very naturally here, must be avoided because it is irretrievably loaded with connotations involving human consciousness. Every cognitive, human self-system is an idiosystem, of course, but in the sense that there are nonhuman systems that are <u>subjects</u>, meaning that they externalize (objectify) "other" systems as objects, the concept "idiosystem" must not be restricted in interpretation to specifically human self-systems.

theory of valuation-decision and, indeed, to a theory of knowledge as well. The creative process (later referred to as "objectification"*) has been found to have a particularly crucial import. Second, the establishment of a prescriptive format for rational control of valuation, which involves the adoption of the perspective of an idiosystem (a decision system as subject rather than as object), was impeded by the observation that any such system is inherently embedded in a hierarchy of interconnected systems characterized by a triadic unit configuration. That is, every idiosystem presupposes† the existence of some supersystem in addition to some collection of subsystems, with the extension of this configuration providing an indefinitely extended hierarchy. Considering the human individual as a reference system, for example, it is surely truistic to observe that the decisions of such an idiosystem are invariably embedded in some context selected from among many complex institutional systems—social, professional, political, religious, and national entities at many levels of organization—and finally perhaps in highly generalized cognitive and cultural systems that are as extensive in scope as the widest reaches theory and history will allow. Similarly, such a system is necessarily connected intimately with a cascade of organic subsystems: neural, muscular, glandular, cellular, and finally even molecular in character.

The complication that enters with this realization concerns the manner in which analogs of the creative, aesthetic, and control processes first identified at the level of cognitive decision systems may now be consistently construed as operative at many levels in hierarchies characterized by increasing systemic complexity. As an additional complication, each subsystem (or supersystem) in the hierarchy associated with a particular idiosystem must be conceived as capable of contributing to any decision process by which a unique line of behavior is ultimately selected. Meaningful consideration of a decision system as a subject must therefore take place in the context of the prototype configurations encircled in Fig. 1a. At least three hierarchical levels, as indicated in Fig. 1b, are necessarily involved in representing the pattern of communication and control that affects decision at the level of an idiosystem.

As indicated in Fig. 2 the operation of decision systems at any level of the hierarchy may be analyzed in terms of comparisons of extrospection (filtered input) with norms that instigate a problematic situation (selected via an aesthetic process) to be resolved by a decision procedure involving objectification (or an analog of this creative process) and selection among objectifications (or an analog of this control process). The extrospection of

*"Objectification" refers to the process of conceptualization, the modus operandi of cognition. As an extension of the more familiar notions of modeling or theorizing, its specific content is perhaps best revealed by the definition of an objectifying statement: a statement, generated by a creative process in an emergent event or act of insight and selected by policy as a basis for inquiry, that externalizes (institutes) a class of related constructs (objects) and provides a prescription whereby these constructs are meaningful and interpretable in terms of finite observations. Examples are (a) Newton's laws of motion and (b) the Schrödinger wave equation. Analogs of objectification in systems less complex than cognitive systems may be identified with the processes of concept attainment, conditioned response, perceptual judgment, reflex extrapolation, and threshold discrimination.

†This shift from the mere observation that decision systems are characteristically embedded in hierarchies to the stronger claim that every idiosystem presupposes a hierarchical configuration is admittedly very abrupt. The justification of such a shift depends on primitive commitments that have been elucidated elsewhere.[2]

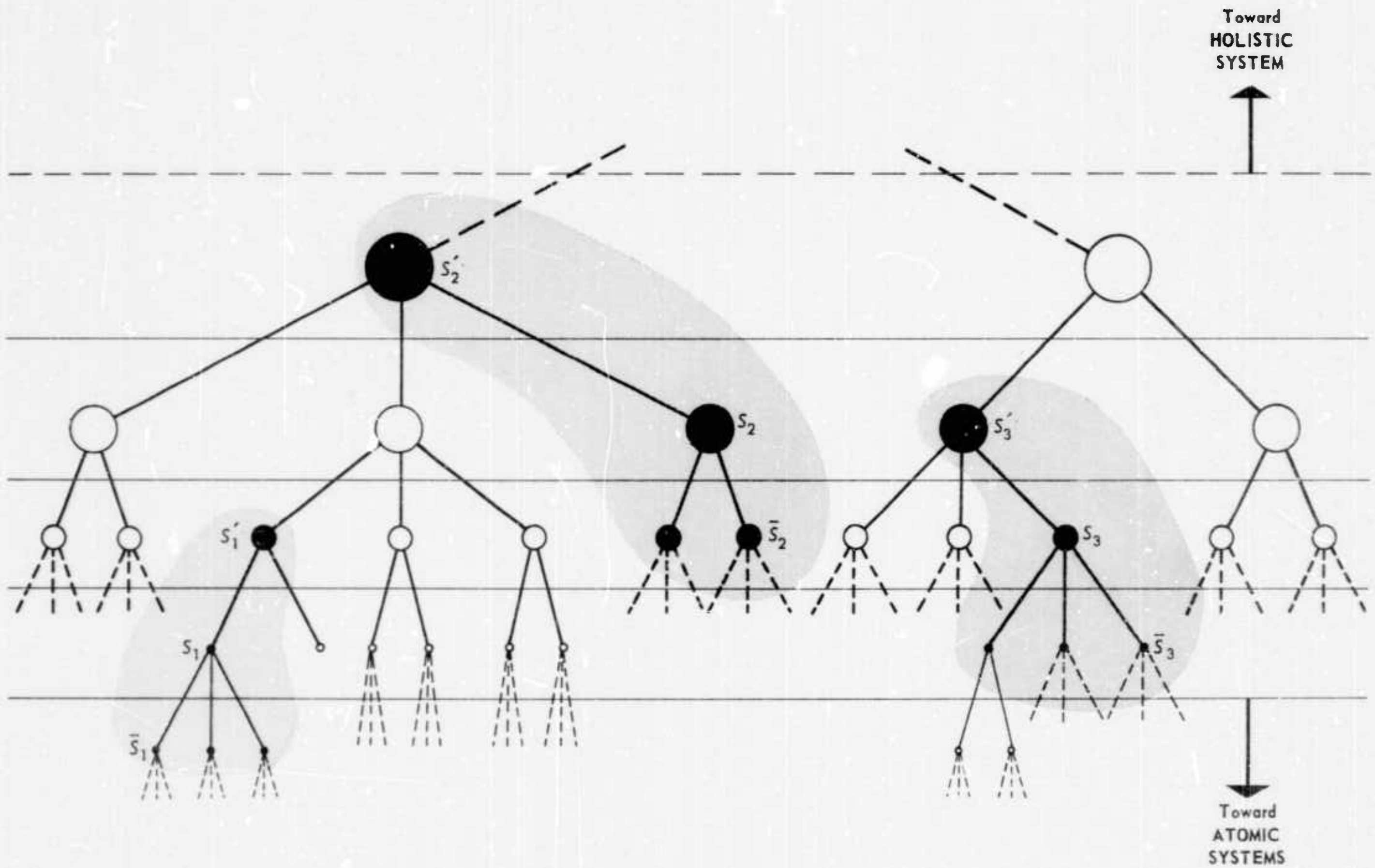
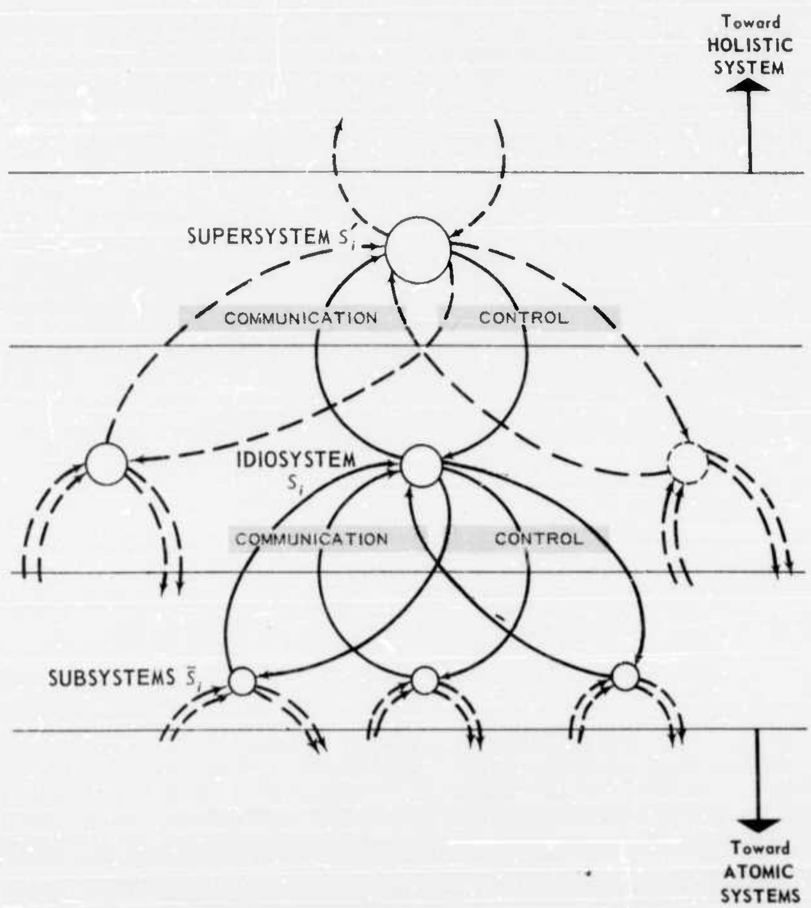


Fig. 1a—Hierarchy of Decision Systems

Prototype triadic configurations.

S_i, an idiosystem of interest at some level in the hierarchy; $\bar{S}_i$, the collection of subsystems of S_i; and S_i', the supersystem of which S_i is an element or subsystem.



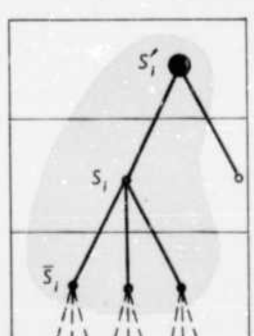


Fig. 1b—Detail of Hierarchy of Decision Systems Showing Idiosystem Communication Control
Schematic regenerative circuits.

Prototype triadic configuration.

any system consists of information input from its subsystems; the decision of any system consists in the exertion of control on the norms of its subsystems. In view of this characteristic regenerative communication-control linkage, the effective hierarchy involved in any decision of an idiosystem may be much more extensive than the triadic configuration (subsystem, idiosystem, supersystem) described as a sine qua non of systems analysis. The diagram of Fig. 2, essentially a model of a cognitive decision system (e.g., a human decision maker), indicates this fact by suggesting the presence of an indefinite

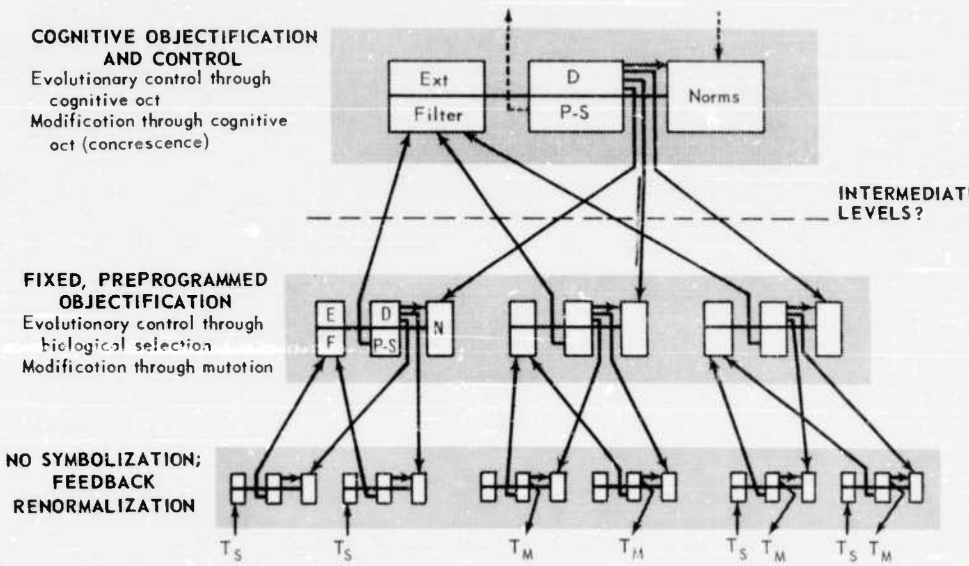


Fig. 2—Objectification and Control in Cognitive Decision System
Ext, extrospection or filtered input; D, decision; P-S, problematic situation; T_S, sensory transducer; T_M, motor transducer.

number of intermediate systematic levels interposed between the cognitive level of organization and the atomic level of sensory-motor transducers. It is important to note that we propose to consider decision at every systemic level as accomplished within an organizational format that is conformal with the pattern of objectification and selection noted at the cognitive level. There are, however, crucial distinctions between decision processes at various levels depending on systemic complexity and hence on distinct capabilities for objectification. This is indicated in Fig. 2 by the distinctions between (a) feedback renormalization, (b) preprogrammed objectification, and (c) objectification as a creative, cognitive act of conceptualization.

As an immediate effect of this realization of hierarchical orders of systemic complexity, the domain of interest for this line of research becomes drastically enlarged. Whereas we have previously been concerned primarily

with the decision process at the cognitive level involving human beings organized in a corporate enterprise, the researcher—on the basis of theorizing in this vein—is now confronted with an inescapable intimation of conformal processes extending possibly throughout a vast hierarchy of levels of organization, both in the direction of increasingly comprehensive supersystems and in the direction of more restricted subsystems.

The problem at this point becomes a matter of structuring the expanded domain of interest in order that strategic choices may be made as to the priority of classes of systems to be investigated in detail. No clearer demand for a relevant taxonomy could possibly be made. Such a demand initiates the second generation of the iterative process of inquiry previously referred to.

Under a poorly structured initial conception of the domain of interest for operations research—with the advantages of certain methodological developments—the construction of theories of decision, valuation, organization, and cognition began. The progress of such an investigation leads, as has been indicated, to an enlarged problematic situation featuring imputed interconnections involving systems at many more levels than the original domain of interest explicitly provided. The appropriate next step is therefore obviously reiteration.

Beginning anew with the project of taxonomizing the presently recognized domain of interest, encountering, no doubt, additional methodological problems, one may hope to find new clues to a consequent theoretical reconstruction. The indefinite prolongation of such an iterative process, achieving at each cycle a reconstruction or refinement of theory, is of course a well-recognized characteristic of the intellectual enterprise in general. It is our interest in thus reemphasizing the very rudiments of inquiry to contribute toward the alignment of systems analysis with a more fully articulated conception of its domain of phenomena and its basic mission.

In particular it is hoped that a delineation of the special role of the prescriptive sciences in the attempt to achieve unified theory covering decision, valuation, and organization will contribute ultimately to a successful resolution of the separations between knowledge, value, and action that have plagued earlier attempts to institute rational control of behavior.

BEHAVIORAL INQUIRY—PERSPECTIVE OF SYSTEMS ANALYSIS

Although we have encountered the problem of systems taxonomy initially from the perspective of the unique province of the prescriptive sciences, it seems quite apparent that the behavioral sciences in general now tend to converge on an identical concern. Despite the diversity of their particular objectives the several divisions of behavioral inquiry commonly share an attenuated version of the situation ascribed to management science: they are all similarly embroiled in metascientific problems both conceptual and methodological in character. This situation results from the fact that a fundamental directive of rational inquiry—the continuing drive toward comprehensiveness—has carried contemporary investigations beyond the limited scope of an earlier scientific preoccupation with deterministic physical systems, i.e., any system whose

successive states may be adequately construed (for predictive purposes) as uniquely determined by observable measures of its present state and the state of its environment.

With the rise to prominence of the social and life sciences, behavioral inquiry* has gradually been brought to a focus on the conception of a type of organization or system singularly in contrast with the reductionistic mechanical systems of classical physical inquiry.

New Order of Theoretical Difficulty

The increase in complexity that distinguishes behavioral systems from the simplistic interaction systems of physics has forced behavioral investigators to conceptualize sophisticated systems characteristics—e.g., selectivity, ultrastability, learning, and simulation—which, though doubtless related to the elemental concept of dynamic mechanical stability, engender a totally new order of theoretical difficulty.

Morris[3] has presented the following outline of the early development in psychology of the concept "attention" that illustrates one aspect of the systems characteristic referred to as selectivity.

> The emphasis upon action implicit in the growth of modern biological science had taken at times an abortive form, as if an organism merely responded mechanically to an environment which itself owed nothing to the organism. Such a position could not long stand in the face of the facts which crystallized in voluntarism as a biological and psychological principle. For American thought, William James had marked the emphasis in pointing out the insurgent character of the organism and the way attention helped to constitute the object of perception. Dewey had isolated the basic point in his 1896 article on "The Reflex Arc Concept in Psychology": perturbations of environment actually constitute a stimulus to an organism only in virtue of the implicit response or interest which sensitizes the organism to selected features of the world capable of furthering the release of the response itself.

McDougall,[4] although he did not use the concept ultrastability explicitly, provided an excellent illustration of this construct in describing the type of behavior he considered to be most characteristic of the living organism.

> Take a billiard ball from the pocket and place it upon the table. It remains at rest, and would continue to remain so for an indefinitely long time, if no forces were applied to it. Push it in any direction, and its movement in that direction persists until its momentum is exhausted, or until it is deflected by the resistance of the cushion and follows a new path mechanically determined .... Now contrast with this an instance of behavior. Take a timid animal such as a guinea-pig from its hole or nest, and put it upon the grass plot. Instead of remaining at rest, it runs back to its hole; push it in any other direction, and as soon as you withdraw your hand, it turns back towards its hole; place any obstacle in its way and it seeks to circumvent or surmount it, restlessly persisting until it achieves its end or until its energy is exhausted.

In his description of the type problem of the kitten and the fire, Ashby[5] has clearly delineated that feature of heuristic modification of characteristic response known as learning.

*The contention here is that, from its twentieth-century origins in the rankest sort of reductionism, behaviorism has gradually been modified (by such efforts as those of Dewey, Mead, Tolman, Cassirer, et al.) to the extent that it now provides the general support for a tremendous range of inquiry, extending at least from the investigation of simple homeostatic machine systems to the investigation of highly complex social organizations.

> When the kitten first approaches an open fire, it may paw at the fire as if at a mouse, or it may attempt to sniff at the fire, or it may walk unconcernedly onto it. Every one of these actions is liable to lead to the animal's being burned. Equally, the kitten, if it is cold, may sit far from the fire and thus stay cold .... Contrast this behavior with that of the kitten after considerable experience: on a cold day it approaches the fire to a distance adjusted so that its skin temperature is neither too hot nor too cold. If the fire burns fiercer, the kitten will move away .... If the fire burns low, the kitten will move nearer .... Without making any inquiry at this stage into what has happened to the kitten's brain, we can at least say that whereas at first the kitten's behavior was not homeostatic for skin temperature, it has now become so. [We are concerned chiefly with one feature of this typical modification of behavior: learning involves the change of a behavioral repertoire from a less to a more beneficial characteristic pattern.]

Finally, in illustration of the concept simulation, it is possible to concoct an instance of the elementary employment of the peculiarly human capacity for "mediated" behavior that John Dewey was among the first to emphasize. Suppose that in the absence of any present necessity to act a war party of primitive men succeed in formulating—by means of significant gestures and crude diagrams drawn in the dirt—a plan for a forthcoming attack. Such selection of behavior, mediated by a symbolic "mapping" technique in the context of a reduction, constitutes the essential feature of cognitive behavior which, by the formalization of languages and other semiotic structures, may be extended into the general enterprise of inquiry for the purpose of behavioral control.

Systems that are characterized, then, by patterns of response that are modifiable via processes involving selectivity, ultrastability, learning, or simulation—that is to say, systems that are adaptive—exhibit such variable activity that they have proved to be generally intractable to investigation under the traditional format of causal determinism. Yet the objectives of inquiry—prediction, explanation, prescription, manipulation—remain to be served no less in the biological and social sciences than in chemistry and physics, the areas of earlier success. The strategy of behavioral inquiry in the twentieth century has therefore understandably consisted in a tendency to accede more and more to the notion that a deterministic basis for explanation (or theory) is essentially inadequate in the study of purposive behavior.

The initial effect of this shift in strategy has been primarily methodological. The development and utilization of stochastic (as against deterministic) models is generally interpreted merely as an attempt to apply probabilistic logic and statistical inference to the analysis of complex systems. Another interpretation of perhaps greater significance, however, and one quite insufficiently recognized at present, follows from the inexplicit conceptual commitment involved in adopting the stochastic format. In any use of a stochastic model a characteristic activity that consists essentially in the generation of a line of behavior via a selection process may be covertly attributed to the system in question. Here "line of behavior" is understood as a particular path through the array of states possible to the system, and "selection" is interpreted in the elementary sense of a resolution of alternatives, by any means whatever, at successive choice points in the phase space and temporal history of such a system. In this light, additional significance must be attached to the utilization of stochastic models insofar as they constitute support for any sub rosa imputation of internal components of systems control that are presumed to be characteristic of instrumental and functional aspects of organization.

Convergence of the Behavioral Sciences

Emerging nearly simultaneously in many specialized divisions of research the conceptualization of adaptive control processes has apparently been an important feature of the decided tendency toward convergence that is now seen to involve the information sciences (cybernetics), experimental life sciences, social sciences, and, as we would maintain, the management sciences. However hazily it may as yet have been conceived, a unitary domain of interest for the whole of behavioral inquiry is gradually emerging, and this domain so far appears to comprise just the range of adaptive systems, in which internal or "idio"-control is conceived as contributing strongly to the collective determinants of behavior. (It is, quite naturally, just this aspect of internal control that is ultimately utilized to distinguish between systems that exhibit behavior and those that exhibit mere interaction.)

Terms variously used to identify general classes of such systems seem to abound in wild profusion. In the field of value theory, Pepper[6] proposes the term "selective" systems; in experimental psychology Tolman[7] has featured the notion of "purposive" systems; in cybernetics Wiener[8] referred to "communications-control" systems; in brain simulation studies Ashby[5] elects to use the explicit term "adaptive" systems, a usage shared by Bellman[9] in decision theory; and in computer technology[10] the current coinage is "self-organizing" systems—and this collection results from the most cursory sampling of nomenclature associated with what the researcher must suspect is a unifiable conceptual domain. Under a rubric of sufficient generality, it appears possible to assimilate a vast range of systems: (a) rudimentary quality-control devices, (b) servocontrolled guidance systems, (c) automated machine complexes, (d) programmed computers, (e) simple organisms, (f) "higher" organisms, even *Homo sapiens*, and (g) human social organizations.

This is the now familiar context of general systems theory. To whatever extent the general systems approach evokes credibility as a line of theoretical advance, one will be disposed toward an attempt to attain a taxonomy of adaptive systems. Such a conceptual task is a prerequisite to the maximum exploitation of intellectual resources, i.e., the reiteration of empirical and formal cycles of inquiry in a continuing refinement of theory. One caveat, however, is glaringly obvious. Any general taxonomic structure that purports to establish conformality among so many apparently disparate entities will be utterly worthless unless it also admits of meaningful distinctions that can be shown to correspond with the several specialized concepts presently being utilized fruitfully in systems analysis. The purpose of this study is to determine whether the concept adaptive system is capable of generating such a general taxonomy.

PRIMITIVE NOTIONS FOR A TAXONOMY OF ADAPTIVE SYSTEMS

To attempt to establish a taxonomy for a complex domain is to return to long-forsaken territory because the procedure of taxonomizing is first of all a complicated version of concept attainment and therefore involves the employment of skills that tend to lapse into disuse with the development of a familiar and habitual structuring of experience. The sophistication acquired in experience is, however, not devoid of advantage. In the sense that Goethe maintained that even an observation is already a theory, the observer is prepared by ex-

perience to recognize that the first structuring of a domain of interest—however crude—constitutes a preliminary theory about the objects of that domain. A fruitful taxonomy of adaptive systems may therefore be expected to progress through successively more rigorous versions characterized first by verbalizations, i.e., models couched in natural language, followed by more nearly operational models perhaps in the form of communication-control flow diagrams, ultimately terminating in acceptable formal or mathematical models. It is possible to anticipate the development of formal models in the case of adaptive systems all the more readily because a cue that strongly suggests the selection of the concept "characteristic response" as a fundamental criterion of classification for adaptive systems already exists. Since characteristic responses of instrumental systems are readily amenable to mathematical representation as formal transformations, we have some basis for beginning this particular taxonomic project with reasonable confidence.

However that may be, the first order of business is to select a working definition of "adaptive system" in order to at least distinguish those systems that are adaptive, collecting them in a common set for the purpose of further structuring. We propose to adopt initially the definition that a system is an adaptive system if its behavior maintains its essential variables within the limits of their respective norms. Here "essential" variables are interpreted to mean those measures of an environment to which the survival of the system is sensitive. (It is important to notice that adaptivity is therefore inherently relative with respect to environment.)

This definition, without explicit mention of its relative character, is due to Ashby[5]; it is apparently in good correspondence with Cannon's[11] earlier concept "homeostasis," and it appears to be well supported by the general principles of physiology.

With regard to a survey of systems in a search for those that are adaptive, there are two standard strategies: the simplistic and the generalistic—or in Bertrand Russell's pungent terms the "simple-minded" and the "muddle-headed." In this case the simplistic approach would consist in beginning with the most elemental system that could be legitimately conceived as adaptive and proceeding by successive complication of the system to cover the whole range of adaptive systems. Conversely the generalistic approach involves an originally coarse screening of all systems to locate those that are adaptive, with successive refinement of the classification process.

That the generalistic strategy should be our choice seems quite clear. On one count the conception of an adaptive system, construed in its simplest version as a negative regenerative system, is already receiving rigorous treatment by a large body of investigators. It is only reasonable to assay a complementary approach as a possibly fruitful alternative. Second, the avowed intention of this study is the attainment of comprehensiveness and very broad generality. We shall therefore initially screen a veritably cosmographic domain of systems, where our "cosmos" is, of course, the local universe of experience and discourse. A grasp of such a total domain of systems depends on a conception of the evolutionary process as the generator of systems of interest. That this format constitutes a presently appropriate context for a taxonomy of behavioral systems is strongly supported by Simpson,[12] who has reported the adoption of this identical basis for a recent symposium concerned with theories of behavior.

. . . It is so universally accepted as not to need explicit statement that . . . there is, indeed, a general theory of behavior and that the theory is evolution, to just the same extent and in almost exactly the same way in which evolution is the general theory of morphology. To make the relationship more obvious and to demonstrate that morphology, physiology and behavior are aspects of organisms all inseparably involved in and explained by the universal fact of evolution became a principal object of the symposium.

In order to emphasize the fact, however, that we are not dealing initially with the technical syncretic theory of evolution presently available to the specialist, the common-sense notion of a process of development will be utilized as a covering term. On encountering specific features that are attributable to this process as a generator of the total domain of organization, we shall have occasion to institute an operational concept of the evolutionary process derived from refinement of the vague notion of development as it appears in the context of natural language.

The Process of Development

The process of development—ultimately evolution—is the product of a fabulous Gedanken-experiment in which some element of the human race has participated in every generation since the initiation of systematic inquiry. The laborious reconstruction of the history of the apparently ceaseless transforming

TABLE 1

DEVELOPMENT SUB SPECIE AETERNITATIS

System	Referent	Domain
Inorganic	Physicochemical aggregations	Geosphere
Organic	Biological organisms	Biosphere
Conceptual	Psychosocial-symbolic organizations	Noosphere
Synthetic	Fabricated entities	Technosphere

activity of our local universe still absorbs the efforts of cosmologists, paleontologists, geologists, biologists, and lately even nuclear physicists. Our information is already detailed enough, however, so that we can readily imagine—as Julian Huxley has suggested—a stopped-frame motion picture of this transformation process that would reveal the successive appearance, development, and deployment of three primary classes of systems: (a) the collection of inorganic entities and aggregations and, superimposed on it, (b) the collection of biological organisms and organizations of organisms and, superimposed on both, (c) the collection of psychosocial or symbolic systems. These collections may be assigned respectively to three general domains with regard to the process of development. Following the usage of Père Teilhard de Chardin,[13] these domains are termed (Table 1) the "geosphere," the "biosphere," and the "noosphere."

Although the geosphere, biosphere, and noosphere constitute exhaustive ontological partitions with respect to a particular set of properties, the class of fabricated systems is appended in Table 1 to indicate that an alternative factorization exists that may ultimately require attention. Quite obviously it

would be possible, if it were thought desirable, to distinguish between natural systems and synthetic systems, i.e., the domain of all structures, machines, and artifacts, fabricated or assembled by the agency of natural systems. This domain, in fact, lies at the center of interest for a number of investigators presently concerned with the design of machine systems that are adaptive—the entire spectrum of work on artificial intelligence and automata. Under the strategy of this particular inquiry, however, it becomes a straightforward decision to submerge this distinction. If a taxonomy of adaptive systems can be carried out in the most general terms, and if this project subsequently leads to increased capability for systems analysis, the project of systems simulation can be readily advanced in due course on the basis laid for theories of adaptive control processes.

Returning, then, to the preliminary classifications represented by the geosphere, the biosphere, and the noosphere, and attempting to encounter adaptive systems in their most general context, the primitive notions that have been advanced in the service of explaining the main features of the process of development are examined.

Figure 3 presents a crude rendering of an initial premise from thermodynamics that asserts the directivity of energy transactions in a unitary total system in progress from an initial unstable dynamic state to an eventual state of static equilibrium via a degradation process involving entropic interactions destined, finally, to deplete the potential of the original state of the system. Superimposed on this process is the posited process of development that features a converse effect consisting of a general increase of variety and organization with respect to metastable subsystems that appear by differentiation within the total system. In contrast with the energy transactions typical of the system as a whole, such subsystems are characterized by locally negentropic reactions.

Four primitive notions—partition, duplication, variation, and competition—are presupposed by the assumption concerning the increase of variety and organization with the appearance of locally stable subsystems. A subsystem could appear only by a process of partition occurring in the unitary system and could participate in negentropic reactions only within the confines of a barrier that permitted a metastable state to exist. Similarly a general increase of variety and organization among negentropic subsystems could not occur in the absence of the combined processes of duplication and variation; the primitive notion of competition is obviously no more than an assertion that the isolated and finite character of the original system must impose on all subsystems the constraints of limited resources. An additional assumption concerning the consistent operation of the system, i.e., the constancy of physical laws controlling change in the system, is generally taken so much as a matter of course that it escapes mention.

These explicit commitments regarding primitive notions underlying the conception of the development process are immediately recognizable as just the determinants of the process of natural selection. For the purpose of this study they provide a particular advantage in that they lead to the delineation of the main features, as well as the subprocesses, of evolution—the specific formative process whereby the population of natural systems is presumed to have been produced.

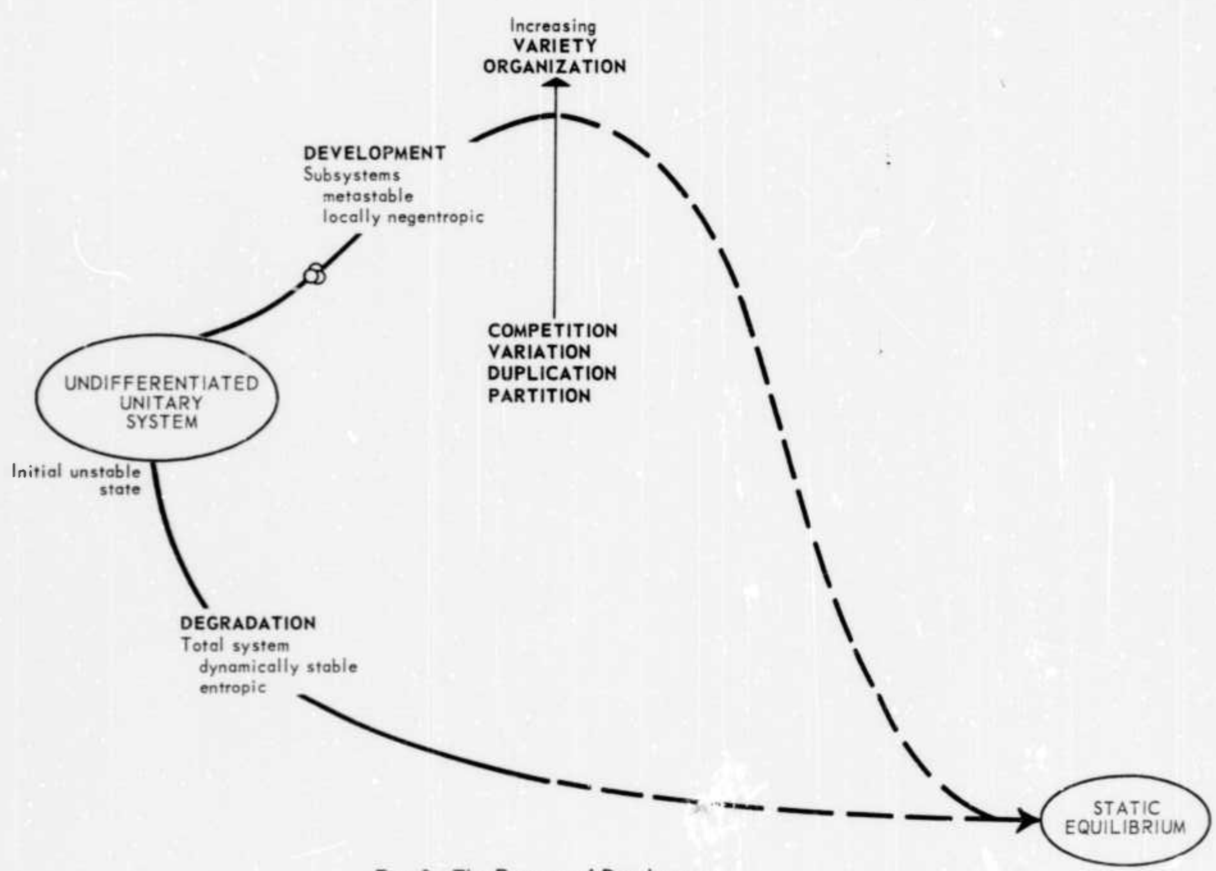


Fig. 3—The Process of Development

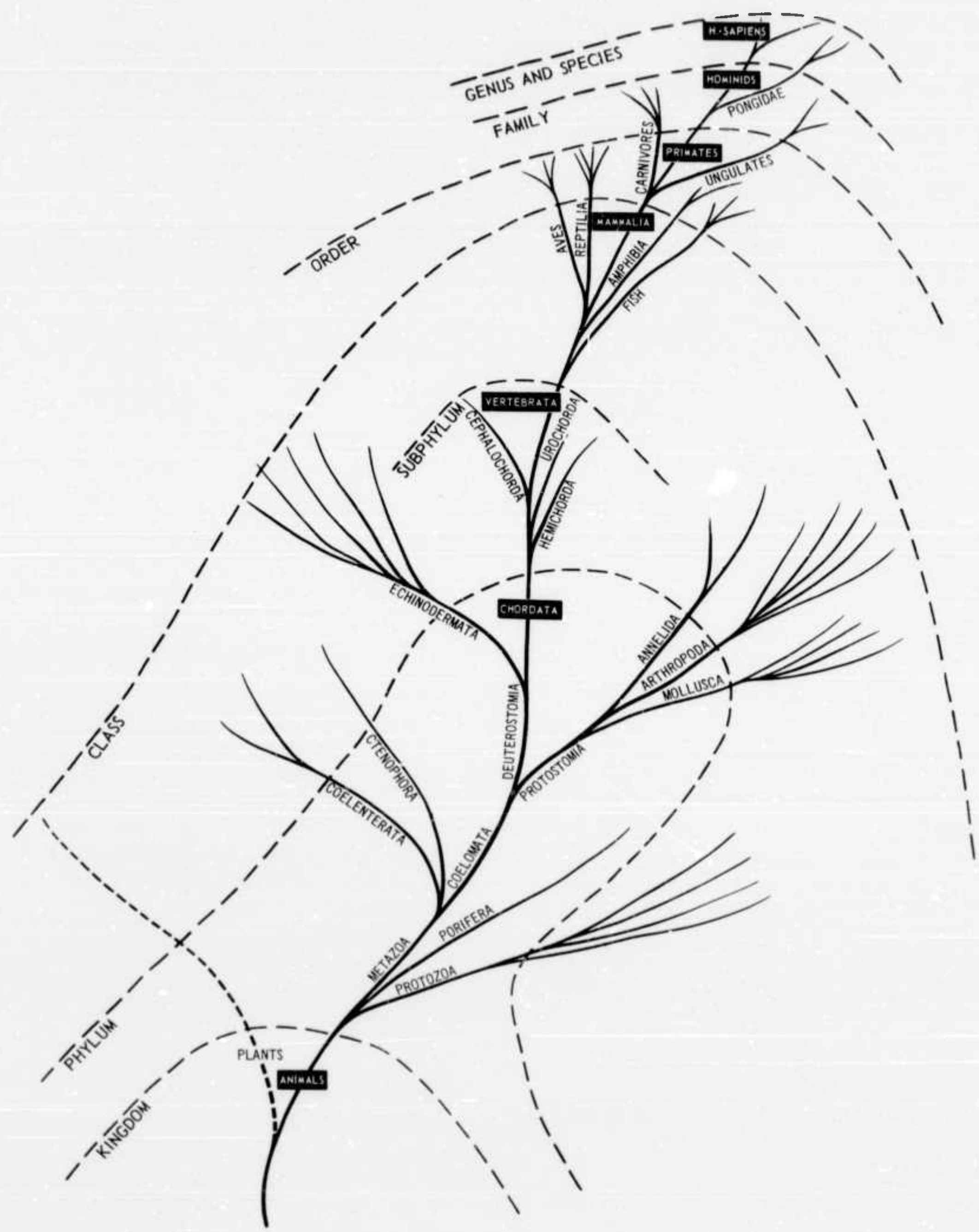


Fig. 4—Successive Displacement—Central Feature of Development

Main Features of Evolution

Patterned on conventional diagrams[14] of the "tree" of life, Fig. 4 shows a simplified version of the development of the animal kingdom. On the basis of this illustration two primary features entailed by the primitive notions partition and competition are most notable: (1) the repeated branching of differentiated organic forms from nodal points (which correspond to the successive morphological divisions of kingdom, phylum, class, order, etc.) and (2) the successive displacement of existing historical populations by the "wedging in" of new populations. This general pattern of successive displacement of dominant groups is presumably to be explained in terms of a combination of subprocesses operating always, as it were, along a "wave front" of development that leaves behind it a historically established array of viable living forms that persist with variable capacity to provide a basis for further exploitation of their particular patterns of organization.

With regard to the specific subprocesses of development, which must be assumed to operate at the lower morphological levels where change is critical, what are the implications of the primitive processes already identified? Using as an illustration the development of the primates, Fig. 5 exhibits the manner in which the four primitive notions allow the development of living forms to be conceived of as a unitary process made up of a number of subsidiary processes. As Huxley[15] has maintained, the individual organism comprises a process of stabilization within the process of the differentiation of a species, which is in turn a process within the radiation of a type, which is, again, a process within the succession of dominant groups. Finally, the overall process of realizing novel possibilities of variety and organization is just what may now be meaningfully referred to as the evolutionary process.

One critical feature of evolution, however, is as yet insufficiently explained. Unless the process of differentiation via mutation is regarded as adequate to explain the appearance of gestalt novelty, some other way will have to be found to account for the characteristic branching that is a marked feature of the history of living forms. The indications from recent theories of evolution, notably that of Simpson,[16] are that an explicit process other than differentiation (Simpson's version is termed "quantum evolution") must be posited. Our own recourse at this point is to interpret the primitive process of partition as entailing the possibility of emergent events. This crucial process of emergence, although at present it constitutes an admittedly vague notion, may at least be factorized in terms of systemic properties (Table 2) and thus be meaningfully incorporated in the collection of subprocesses comprising the concept of evolution.

Primitive Notions and the Process of Natural Selection

In summary of the processes involved in evolution—or natural selection—Fig. 6 indicates the identity and interdependent effects of the several subprocesses on purely figurative three-dimensional axis systems. Referring to the primitives, the partition process entails the sporadic appearance via emergence of novel individual entities as locally stable subsystems. The combined primitives of duplication and variation entail the differentiation of genotypes followed by the radiation of phenotypes under competition for ecological

TABLE 2

PROPERTIES OF EMERGENT SYSTEMS

Property	Explication
Gestalt novelty	A feature of organization based on a novel format; in contrast with combinatorial novelty, which may be attributed to any distinctive aggregation of elements from a given collection, gestalt novelty is a property of an assemblage of elements that introduces structural innovation via the institution of a new form of organization
Concrescence	A process consisting of the "growing together" of previously distinct systems to form a unitary, integral structure; chemical evolution provides very clear examples, e.g., the coalescence of lipid and polymeric molecules in the formation of biological cells; in the realm of ideas, concrescence might be illustrated by the formulation of a theory that encompasses two or more previously disparate theories
Systemic extension	The organization of elements (themselves systems) in hierarchical levels connected by regenerative information-control linkages providing for selectivity at every level represents the basic connotation of "systemic character"; in an emergent system this character is maintained with the incorporation of a new level of organization; this is the most radical version of adaptability as a means to continuing viability
Normative innovation	The appearance of an additional level of organization requires the institution of norms relevant to selectivity at that level; for example, objectification as an emergent event involves not only the conceptualization of related object constructs but also the institution of norms controlling selection among object constructs
Subsystem specialization	In addition to the institution of new levels of organization and new norms, emergence involves the modification of previous subsystems in terms of (a) articulation or differentiation of structure and (b) renormalization or normative innovation; this property of emergent systems is associated with the increasing complexity, efficiency, and elegance of both structure and behavior that mark those systems that are viably competitive under external (i.e., environmental) selection
Negentropy	Two features—(a) the transfer and transformation of energy with net gain of potential by a local, metastable system and (b) the communication and transformation of information with an increase in degrees of freedom in the "decision space" of such a system—constitute properties of an emergent system that provide the possibility of a general increase in variety and organization

niches wherein they establish group dominance. These processes, occurring under the constraint of finite resources, result in the long-range successive displacement of dominant groups via natural selection.

Although selection is indicated specifically as effecting the succession of dominant groups, it is to be noted that selection does in fact operate at every morphological level. Any novel entity that initially appears is a putative genotype. However, if it does not succeed in maintaining stabilization, its pattern of organization has proved nonviable under selection. Similarly phenotypes that do not successfully contribute to the exploitation of an ecological domain by some dominant group are ultimately aborted by selection.

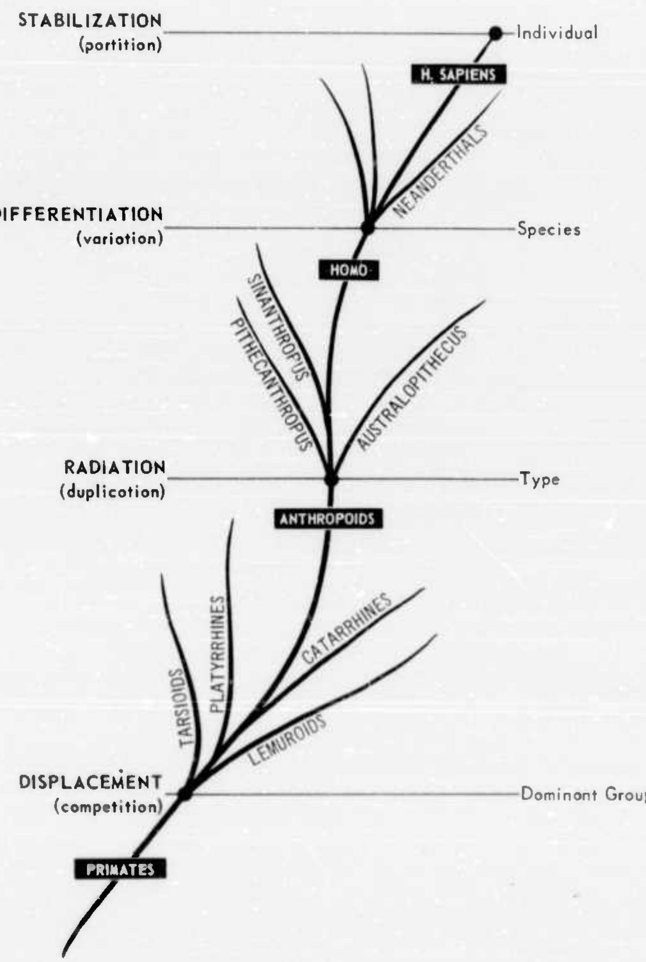


Fig. 5—Subprocesses of Successive Displacement

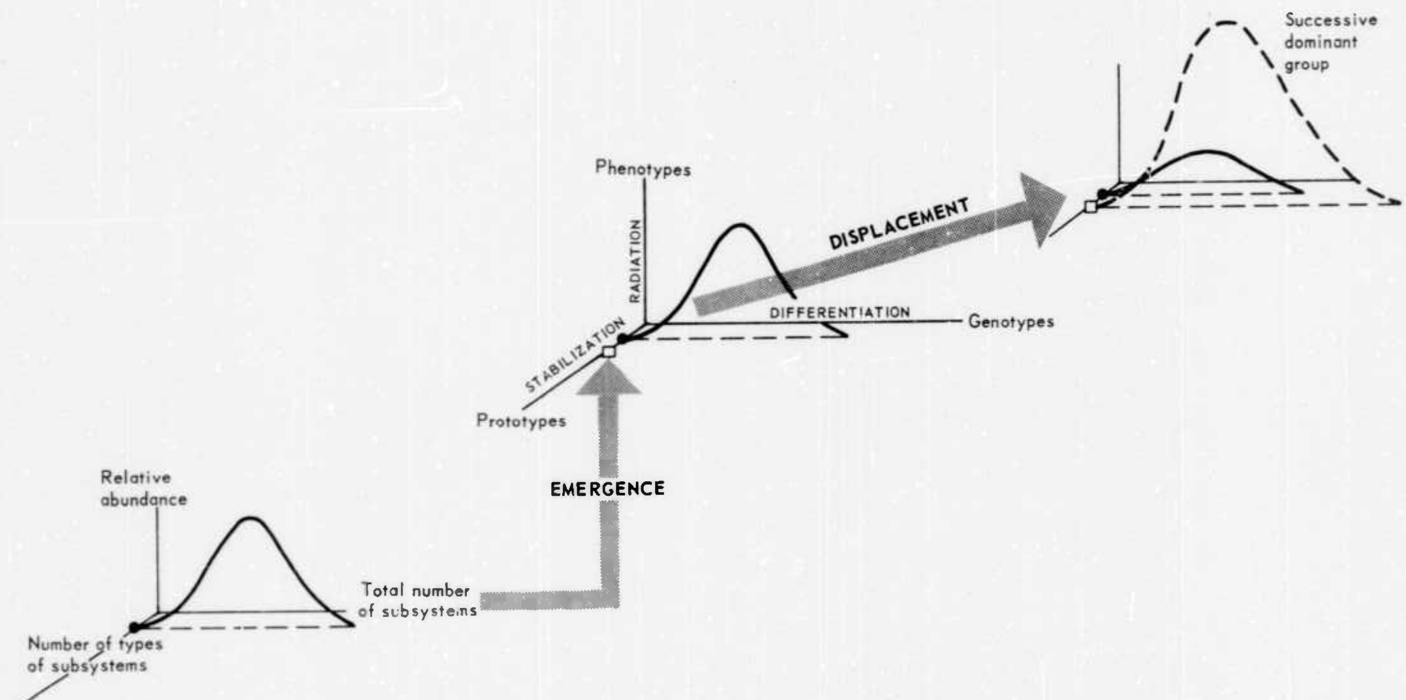


Fig. 6—Natural Selection in the Evolutionary Process

The result is a revelation that might well have been foreseen. Under our definition of an adaptive system as one that maintains its essential variables within the limits of its norms, it is seen that every system emerging in the process of natural selection will necessarily be an adaptive system, for an adaptive system in this sense is just precisely a survival system. Adaptive behavior is equivalent to the adjustment for survival of a viable system; the whole business of natural seleetion, and perhaps of any selective dynamic system, amounts to the automatic generation of subsystems that are specially resistant to the perturbations characteristic of some particular subenvironment of the total system, i.e., subsystems that are particularly suited to survive in their local environment.

The strategy of surveying the total domain of evolutionary systems for the purpose of identifying among all possible systems only those that are adaptive appears to have the diseoncerting result of showing that no such discrimination is possible. There are, however, distinctions that can yet be tried. From the mere fact that all systems produced by natural selection are adaptive, it does not follow that they are therefore adaptive in the same sense or to the same extent.

One may attempt at this point to utilize the faet that adaptivity is relative to environment. For example, an individual entity that endures through some life cycle has proved adaptive only with respeet to the extremely restricted environment of its temporal locus. What eounts in competition at this level is action, and therefore a system that is viable in this sense might be termed an "action-adaptive system." This injection of a qualifier on the basic notion of adaptation presents the possibility of further diserimination among the domain of adaptive systems, which now is taken to be identical with the total domain of evolutionary systems. Under this strategy it is possible to attempt to classify adaptive systems in terms of their environmental range.

One significant observation, however, needs to be entered as a precaution. An unfortunate tendency to hypostatize such eoncepts as speeies and groups is a serious obstruction to clarity. Without prejudieing the eoncept "organization," it is necessary to stipulate that behavior under norms may not be meaningfully attributed to mere populations (in this case species and groups). Therefore, when an examination of the charaeter of adaptation in the context of speeies and groups is undertaken, it is important to keep the point firmly in mind that, as its individuals go, so goes the species—and the dominant group.

Returning to the attempt at classification, if an entity endures through time to establish a genotype, with succeeding modifications enabling the exploitation of some ecological niche, this is an indication that the individuals historically comprising the genotypic population are at least adaptive with respect to a broad environment that is being competitively exploited by various other species. The criterion of sueeessful competition in this context—over and above adaptive action—is a capability for the modification of norms. Systems that are adaptive to this extent would be termed "norm-adaptive systems."

Finally, if a phenotypic population survives through time to establish dominance as a sueeessive replacement to some previous group, this is an indication that the individuals of its component species have proved adaptive with respect to an environmental range so broad that important shifts in the eharacter of its original environment may have occurred. Such shifts of environment are, in fact, a major feature in the selection of successive dominant

groups. What counts for success at this level of competition is a capability for modification of organization, where "organization" is implicitly construed as constituting control of normative modification. Systems that are adaptive to the extent that their organization becomes modified would naturally be termed "organization-adaptive systems."

Now it is a straightforward conclusion that systems that are "persistent," in that they have proved viable through an appreciable duration of geological time, must be construed as adaptive in all three of the senses delineated. This is to say that various analogs of reaction, renormalization, and reorganization are operational characteristics of all systems persisting via the process of natural selection. Systems that are not adaptive in all these senses, e.g., unstable fundamental particles or deleterious mutants, are necessarily ephemeral when considered from the aspect of the geological time scale.

Thus, even a qualified notion of adaptive system seems to lead finally to a situation in which no fruitful distinctions are possible with regard to classification. The process of natural selection may nevertheless be viewed, in the light of this consideration, as portraying the singular drive of a unitary dynamic selective system toward realization of successively more sophisticated forms of viable organization. A unique line of behavior on the part of the total system might be identified with that "leading edge" of emergence that connects just the successive dominant groups appearing along the primary course of historical development. In a very real sense this line of successive emergent systems may be said to embody a continuing course of "improved," i.e., more adaptable, organization; although the persistence of archaic systems indicates that "success," as distinguished from evolutionary "progress," can certainly be achieved by systems that are viably adapted despite their having been superseded in the general advance toward sophistication by successively more adaptable systems.

TAXONOMIC FRAMEWORK

It certainly appears worth while to pursue the identification of just those emergent systems that have initially exhibited, as innovations in their time, features of viable organization that have tended to become stabilized throughout the subsequent course of development. A structure representing the historical succession of emergent systems can obviously provide a natural taxonomic framework for at least an ordering of adaptive systems in terms of a hierarchy of successively more sophisticated systems characteristics, both structural and functional.

The identification of emergent systems depends, of course, on historical reconstructions derived from many special disciplines. Nevertheless the task is not so formidable as it might appear, because of an implication that follows from the competitive basis of natural selection. That implication is that evolutionary emergence is correlated with increasing systemic complexity. Since successive dominant groups must prevail by virtue of superior elegance, precision, efficiency, and adaptability of both structure and behavior, they are identifiable on the basis of the characteristics of gestalt novelty, concrescence, subsystem specialization, and normative modification—crude but effective measures of increasing orders of systemic complexity that have previously been associated with emergence.

A major complication here involves the distinction between an emergent increase in order of complexity and the general increase in the scope and degree of complexity of systems attributable to combinatorial novelty and sheer aggregation. With regard to the organizations of organisms (e.g., symbiotic aggregations, colonies, tribal and familial groups, cultural societies) sometimes referred to as "supraorganisms," this distinction is somewhat difficult

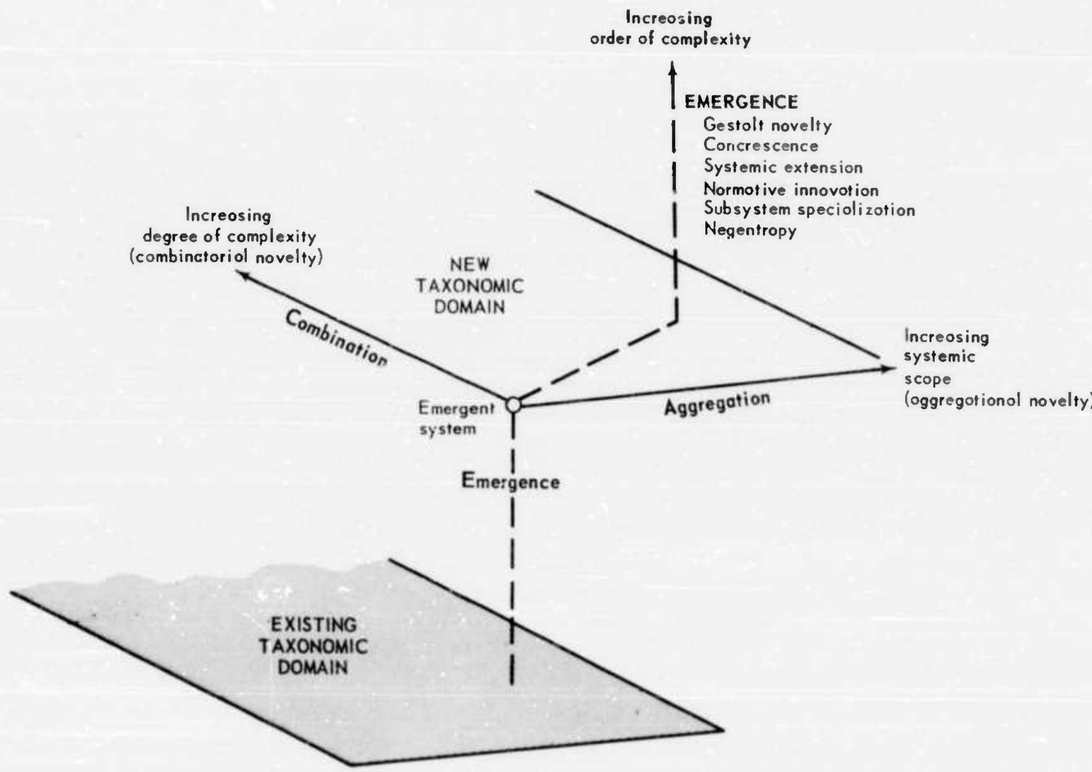
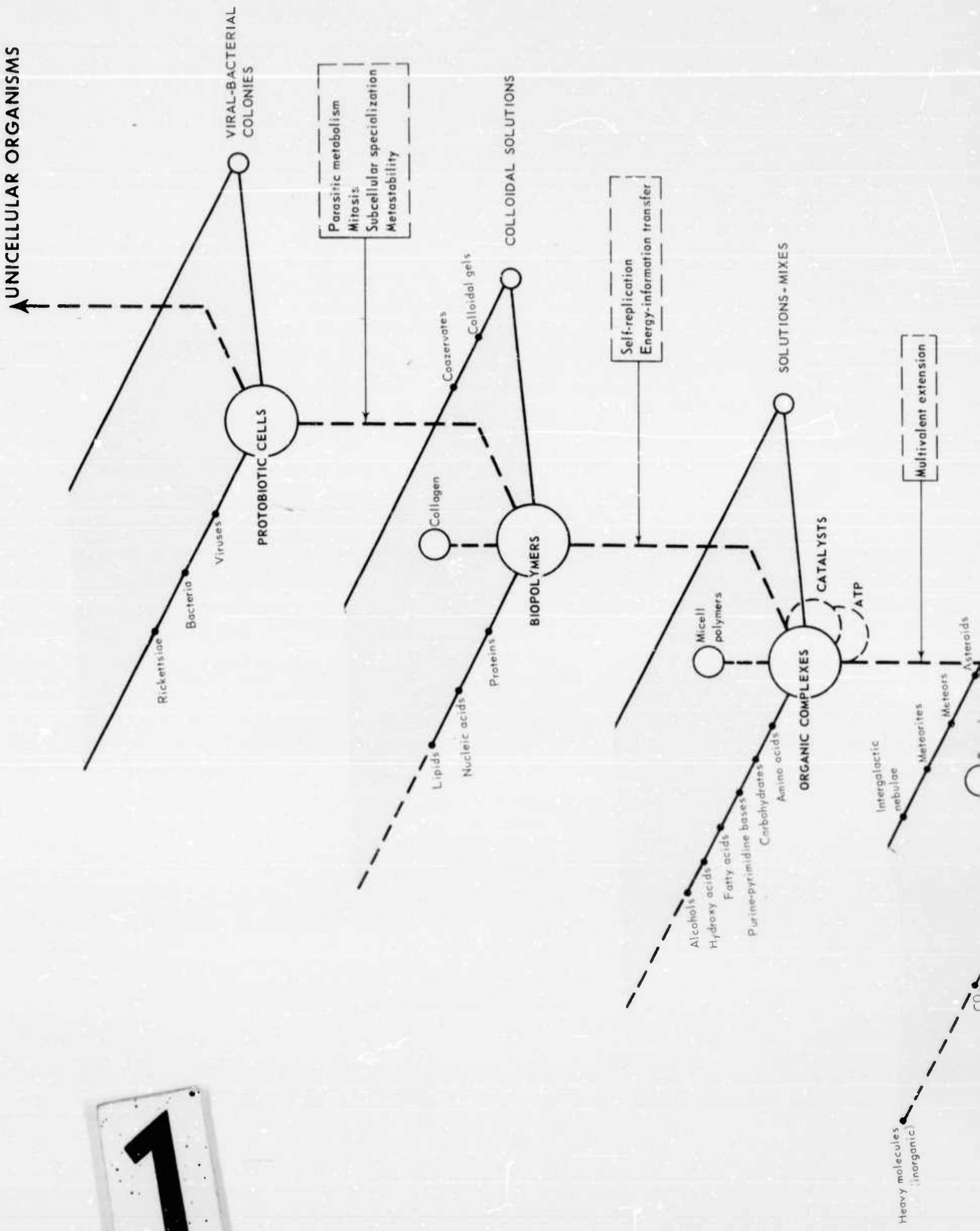


Fig. 7—Emergence and Systemic Complexity

to maintain. In the domain of psychosocial systems particularly, organizations of organisms clearly enter directly into the emergent process. But as a basic format of classification it appears advisable to attempt to distinguish (as in Fig. 7) properties of emergent systems from those of combinations and aggregations.

Such a format provides for the construction*,[14,17–24] of "lattices" (Figs. 8 to 11) that exhibit, for the geosphere, biosphere, and noosphere, respectively, a hierarchical configuration of emergent systems arising within the total system of natural selection. In these lattice structures the appearance of an emergent system is indicated by a "quantum jump" vertically along the dimension of

*References 14 and 17 to 24 provide the material utilized in the construction of Figs. 8 to 11.


UNICELLULAR ORGANISMS
VIRAL-BACTERIAL COLONIES
Parasitic metabolism
Mitosis
Subcellular specialization
Metastability
PROTOBIOTIC CELLS
Rickettsiae
Bacteria
Viruses
COLLOIDAL SOLUTIONS
Coazervates
Colloidal gels
Collagen
BIOPOLYMERS
Lipids
Nucleic acids
Proteins
Self-replication
Energy-information transfer
SOLUTIONS-MIXES
Micell polymers
ORGANIC COMPLEXES
CATALYSTS
ATP
Alcohols
Hydroxy acids
Fatty acids
Purine-pyrimidine bases
Carbohydrates
Amino acids
Multivalent extension
Intergalactic nebulae
Meteorites
Meteors
Asteroids
Heavy molecules (inorganic)

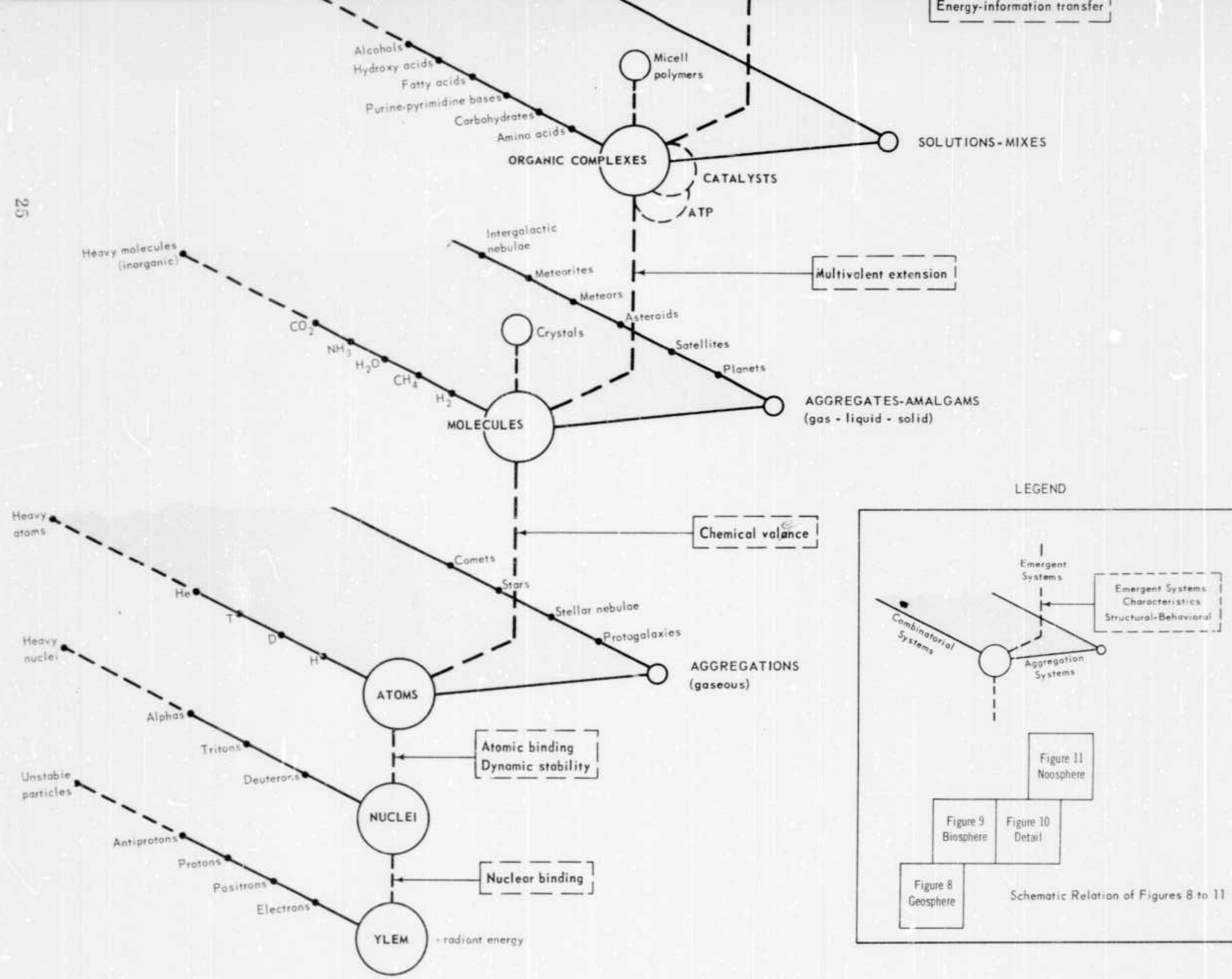
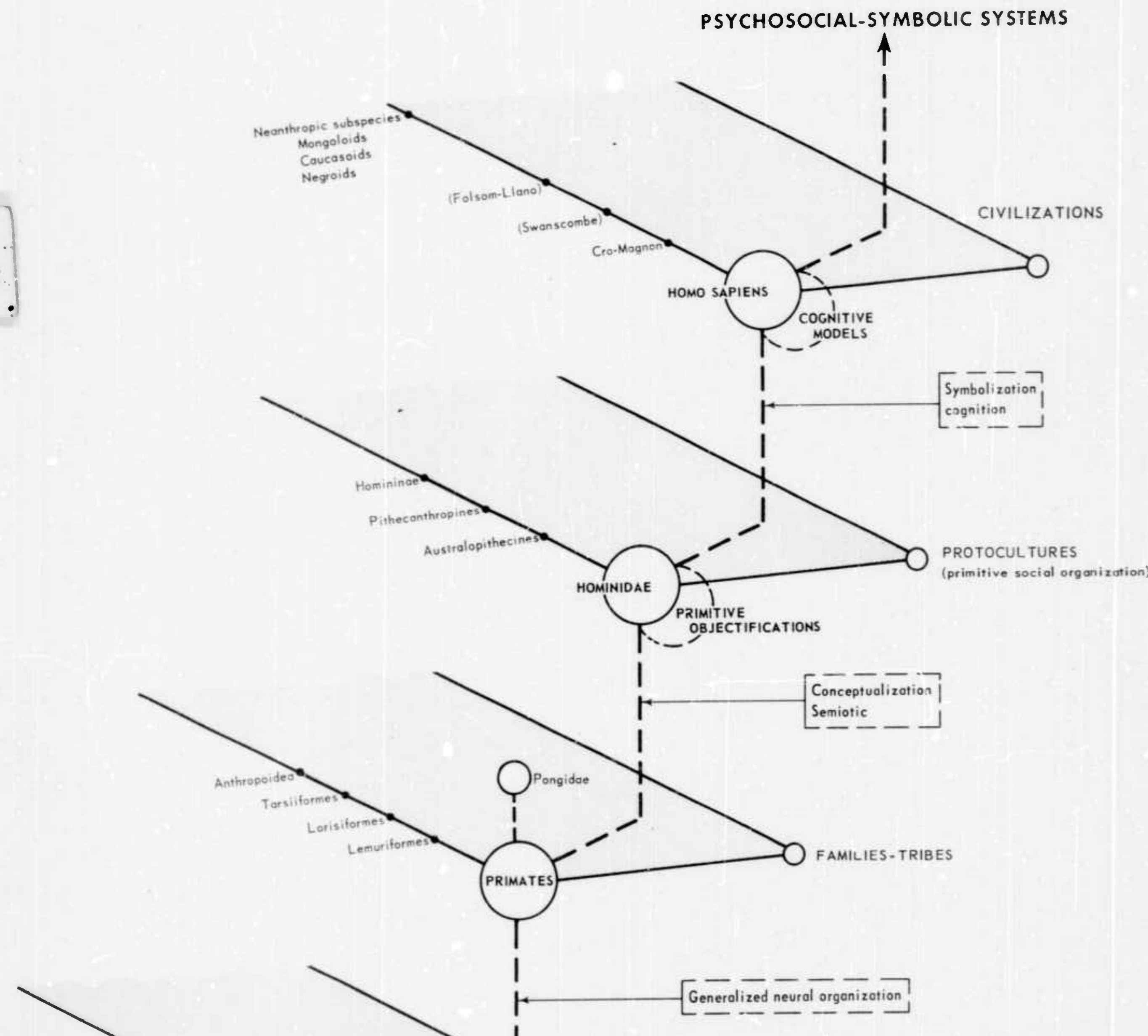


Fig. 8—Emergent Systems, Geosphere


PSYCHOSOCIAL-SYMBOLIC SYSTEMS
Neanthropic subspecies
Mongoloids
Caucasoids
Negroids
(Folsom-Llano)
(Swanscombe)
Cro-Magnon
HOMO SAPIENS
COGNITIVE MODELS
CIVILIZATIONS
Symbolization cognition
Homininae
Pithecanthropines
Australopithecines
HOMINIDAE
PRIMITIVE OBJECTIFICATIONS
PROTOCULTURES
(primitive social organization)
Conceptualization Semiotic
Anthropoidea
Tarsiiformes
Lorisiformes
Lemuriformes
Pongidae
PRIMATES
FAMILIES-TRIBES
Generalized neural organization

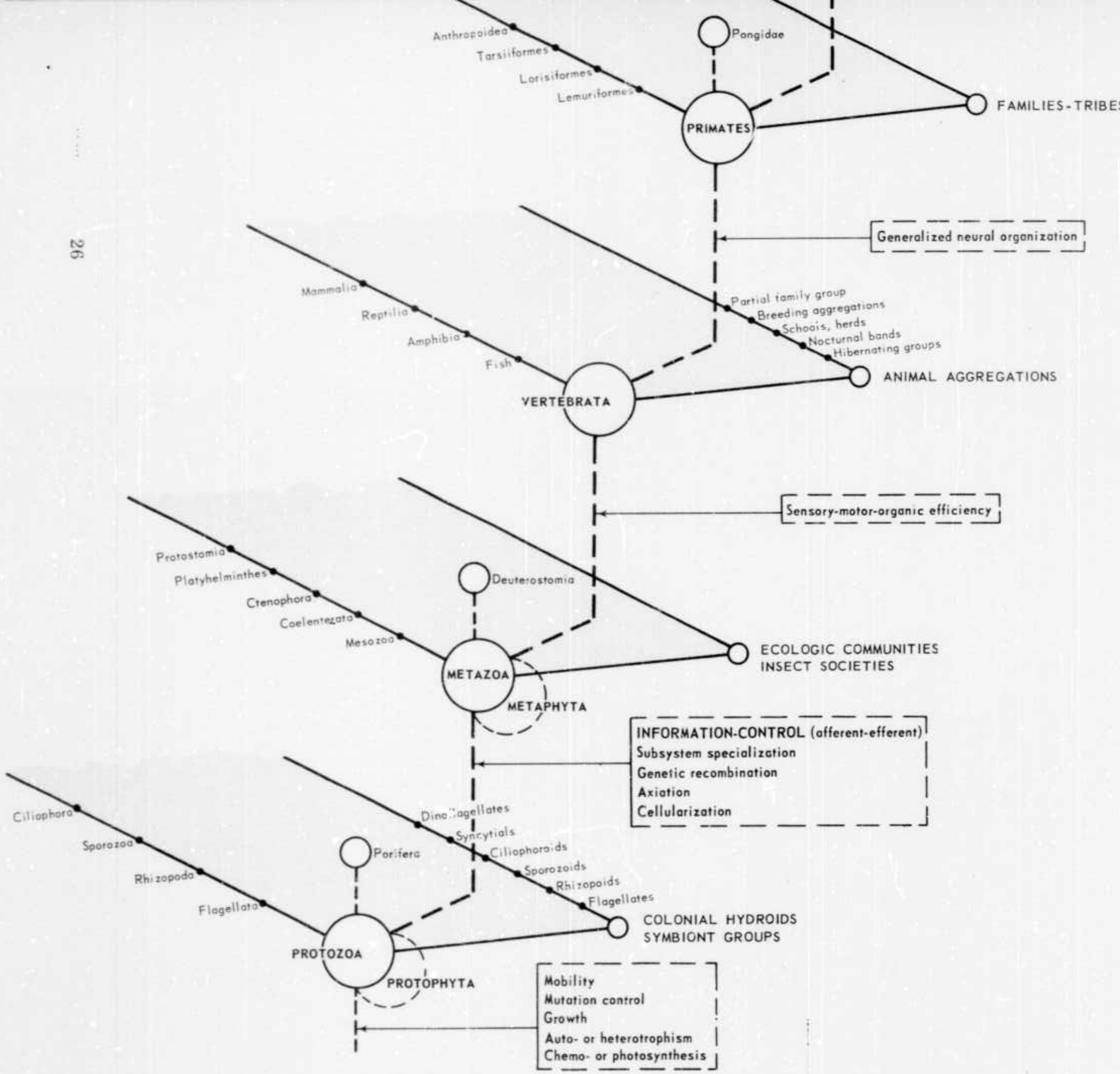
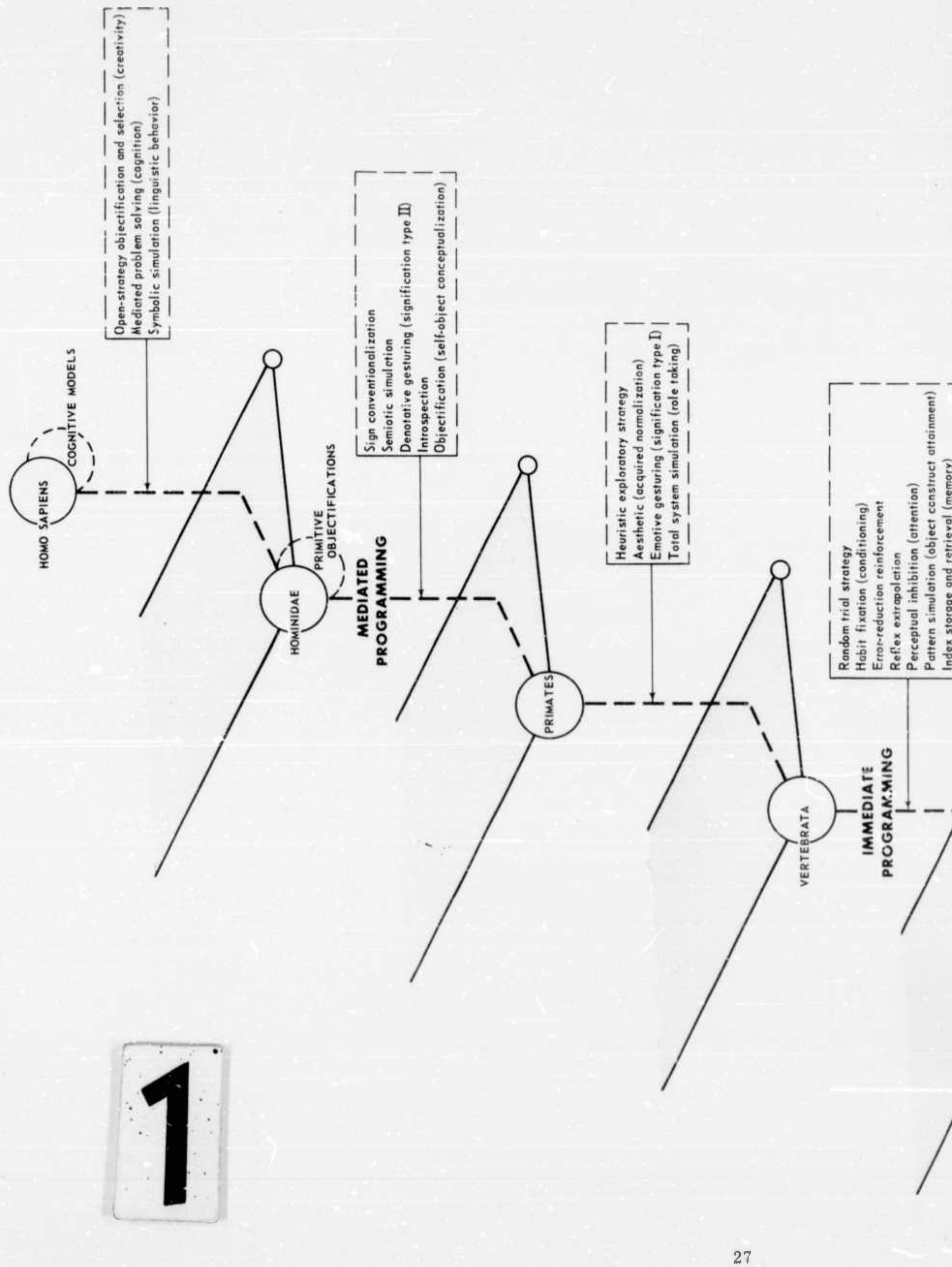


Fig. 9—Emergent Systems, Biosphere


HOMO SAPIENS
COGNITIVE MODELS
Open-strategy objectification and selection (creativity)
Mediated problem solving (cognition)
Symbolic simulation (linguistic behavior)
HOMINIDAE
PRIMITIVE OBJECTIFICATIONS
MEDIATED PROGRAMMING
Sign conventionalization
Semiotic simulation
Denotative gesturing (signification type II)
Introspection
Objectification (self-object conceptualization)
PRIMATES
Heuristic exploratory strategy
Aesthetic (acquired normalization)
Emotive gesturing (signification type I)
Total system simulation (role taking)
VERTEBRATA
IMMEDIATE PROGRAMMING
Random trial strategy
Habit fixation (conditioning)
Error-reduction reinforcement
Reflex extrapolation
Perceptual inhibition (attention)
Pattern simulation (object construct attainment)
Index storage and retrieval (memory)
1

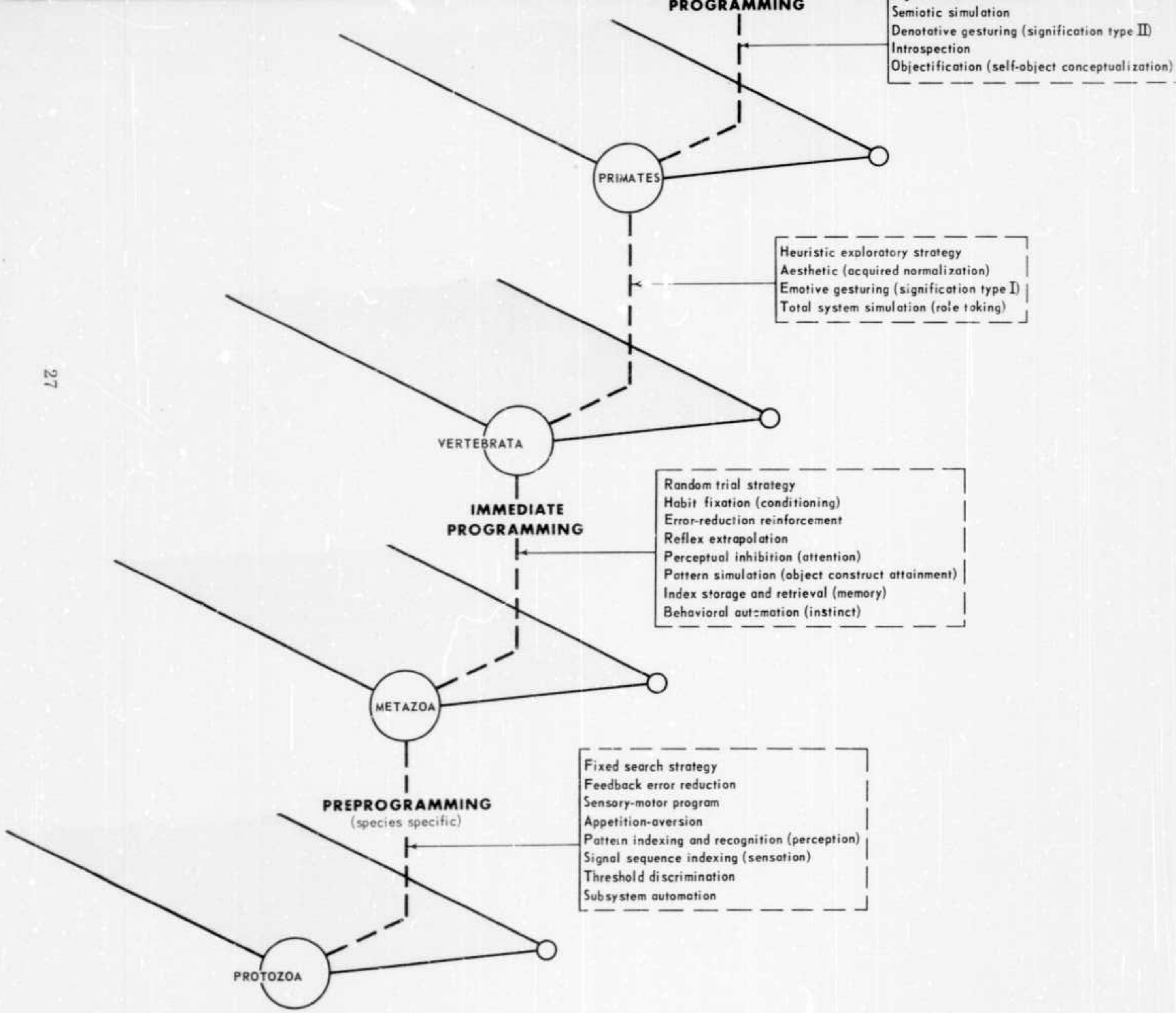
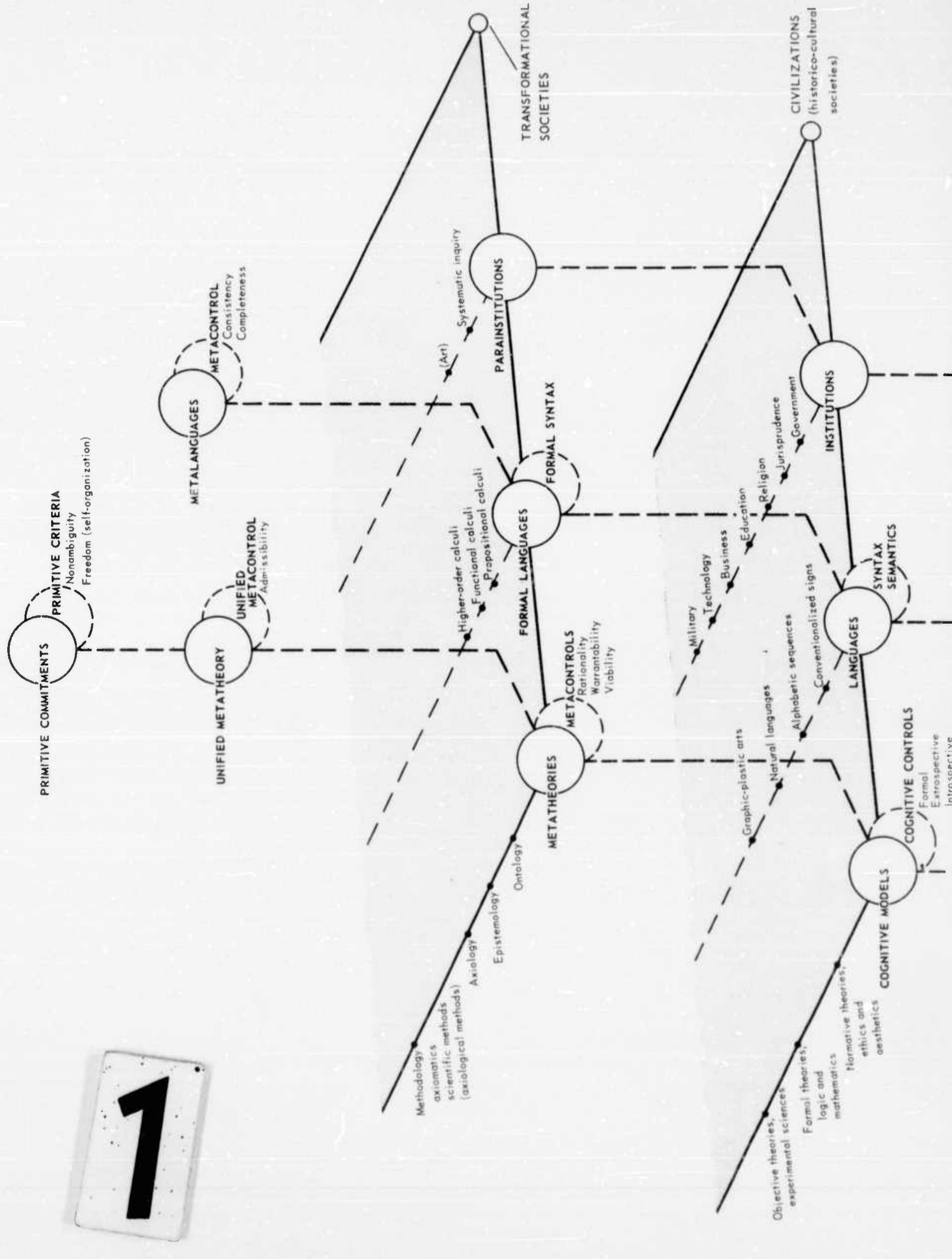


Fig. 10—Detail of Emergent Systems, Biosphere
Information-Control Process


PRIMITIVE COMMITMENTS
PRIMITIVE CRITERIA
Nonambiguity
Freedom (self-organization)
METALANGUAGES
METACONTROL
Consistency
Completeness
UNIFIED METATHEORY
UNIFIED METACONTROL
Admissibility
TRANSFORMATIONAL SOCIETIES
PARAINSTITUTIONS
Systematic inquiry
(Art)
FORMAL LANGUAGES
FORMAL SYNTAX
Higher-order calculi
Functional calculi
Propositional calculi
METATHEORIES
METACONTROLS
Rationality
Warrantability
Viability
Methodology
axiomatics
scientific methods
(axiological methods)
Axiology
Epistemology
Ontology
CIVILIZATIONS (historico-cultural societies)
INSTITUTIONS
Military
Technology
Business
Education
Religion
Jurisprudence
Government
LANGUAGES
SYNTAX
SEMANTICS
Graphic-plastic arts
Natural languages
Alphabetic sequences
Conventionalized signs
COGNITIVE MODELS
COGNITIVE CONTROLS
Formal
Extrospective
Introspective
Objective theories, experimental sciences
Formal theories, logic and mathematics
Normative theories, ethics and aesthetics

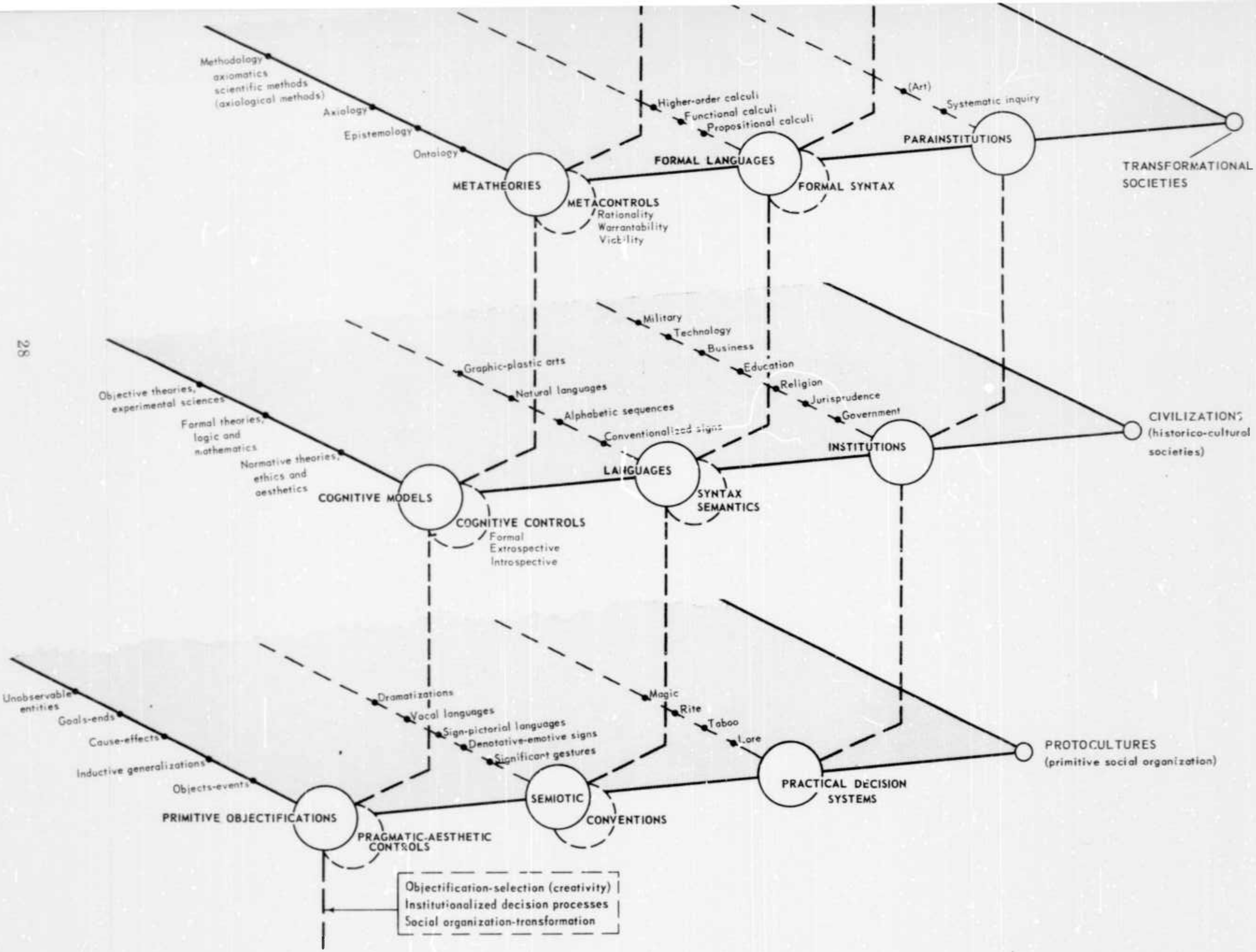


Fig. 11—Emergent Systems, Noosphere

increasing order of systemic complexity. Increasing systemic scope and degree of complexity—secondary in significance for the taxonomic project—are merely suggested roughly by lateral displacement.

Taxonomic Refinement

With the attainment of a unitary hierarchy of emergent systems it is clear that we have available a taxonomic framework capable of effecting a rudimentary ordering of the domain of adaptive systems. The immediate requirement for further taxonomic refinement is the formulation of some continuous measure of systemic complexity. Such a measure must provide the resolution necessary for classifying adaptive systems in detail within the context of the basic conformality provided by their common property of viable organization.

In pursuit of the previous intimation that the concept "characteristic response" may provide the clue to the fine structure an attempt has been made to enter, at each step of emergence (Figs. 8 to 11), some indication of the more important advances in behavioral capability. With the psychosocial systems of the noosphere the increasing sophistication of characteristic response culminates in two vastly complicated procedures: the objectification of (1) object-constructs and theories and (2) norms or controls for selection among object-theories. It must therefore be anticipated that the formulation of a continuous measure of systemic complexity based on increasing sophistication of characteristic response (which is almost certainly correlated with the complexity of structural features) will require extensive creative effort. At present a very promising approach is suggested by the possibility of typifying adaptive systems by a measure defined on degrees and ranges of semiotic freedom, i.e., free capacity of the system available for control of its behavioral program. In common-sense terms, such an approach would feature the classification of adaptive systems in terms of the extent to which their characteristic responses approach autonomy, i.e., self-organization involving the absorption of degrees of freedom by programmed decision procedures.

Even in advance of being able to accomplish such a refinement, however, the present taxonomic framework lends impetus to a significant but so far tenuous reorientation of behavioral theory. (This effect is characteristic of the iterative process of inquiry described earlier.) In order that this implication of the proposed taxonomy may be appreciated a summary of the successive strategies that have been used to direct behavioral inquiry is given here.

Objective vs Normative Theory

With the intention of extending the scope of scientific explanation to include biological, psychological, and social systems—as superimposed on the mechanical systems of physics and chemistry—behavioral inquiry was initially undertaken from the classical perspective of objective theory. "Objective" theory refers to a theory constructed (a) in an observer-object context and (b) under a stringent conception of admissible investigative procedure. Explicitly the following commitments comprise the essentials of a theoretical approach featuring the repudiation of subjectivity, which so vitiated early inquiry, and its replacement by the criterion of objectivity.

(a) Observer-Object Context. (1) Recognizing the inevitability of a subject-object relation at the basis of the experimental method, emphasis is placed on a

laudable effort to maintain a disinterested attitude on the part of the subject or observer. The quite human but nonetheless obstructive tendency of investigators to become involved in the rationalization of a personally satisfying hypothesis is excoriated. As Bernard[25] maintained in his prescriptives for the experimentalist, the preconception of hypothesis and experimental design—which is creative and subjective—must be absolutely severed from the observational phase of inquiry. To experiment is to put a question to nature, and when nature answers the observer must be completely submissive. He must see what is there, no more or less, regardless of his prior commitments and interests. Every question shall be resolved on its merit as the facts determine, and facts shall be construed as only those observations that are open to public scrutiny by at least a coterie of competent and independent investigators.

The creative role of the inquirer as subject, like the origin of his assumptions and hypotheses, has no formal status whatever in this version of scientific method. The resources and procedures of creative insight, being subjective in character, are totally outside the consideration of objective theory. The control of the procedure for confirmation of hypotheses, not the control of the strategy of inquiry, is taken to be the domain of scientific methodology.

(2) This severance of subjective aspects of the observer-object relation clearly presupposes prior commitment to the particular ontological-epistemological position termed "realism." Owing to the antimetaphysical bent of objectivists in general it is difficult to obtain a definitive statement of this commitment. Nevertheless it is surely unquestionable that the prescriptions in para 1 can be countenanced only under the assumption that the objects of any inquiry are sufficiently independent of the observer (subject).

Several notions familiar even to common sense are present in this view: that there is some particular, definite "way things are" (equivalent to the conception of things-in-themselves as comprising reality); that "things" are independent of thoughts about things; that facts, peremptory in character for any observer, ultimately constrain the concepts and theories that are warrantable, while being in no way constituted by the preconceived concepts and strategies associated with the creative role of the observer; and that the attainment of theories confirmed by the facts in a given domain comprises a continuing process of discovery that, in the limit, approaches the truth about nature owing to successive replacement of disconfirmed hypotheses by others sufficient to cover the facts so far set forth.

(b) Format of Inquiry. As a process of discovery the objective-theoretic approach features the following investigative procedure, generally termed the "experimental" method:

(1) Analysis of an object system, as independent of the observer, to achieve a factorization of measurable properties to which the behavior of the system is sensitive.

(2) Correlation of these measures over some range of states of the system, where this range may be generated in part by perturbing the system.

(3) Formulation of functional relations expressing, as generalized correlations, the characteristic dependency of each defined measure on some collection of "primitive" measures, where such generalization involves the adoption of some formal model furnishing the logical format of relations.

(4) Design of experiments to test the resultant theoretical model for adequacy (primarily precision and comprehensiveness) of prediction with regard to states of the system not previously observed.

(5) Confirmation of the theory on the basis of the correspondence of predicted observations with relevant experimental evidence—a procedure originally construed as verification under the control of binary (true-false) logic, despite the realization that technically the testing of theories by their consequences might be expected to achieve only probability, not certainty, as a measure of confirmation.

(6) Reiteration of this procedure to increase the scope of the predictive capability of successive modifications of the model or theory.

This pattern of inquiry, presumably originating as early as Galilean physics, had proved spectacularly successful for predicting and explaining a wide range of inorganic systems in the domain of the geosphere. Persistent attempts to extend this success in early behavioral inquiry, however, encountered intractable problems* when confronted with the modifiability of characteristic response (literally the adaptivity) of organic systems typical of the biosphere.

Explicitly the crux of the difficulty lay in the general character of the response of organic systems to perturbations induced by an experimenter-observer. For a very numerous class of systems treated under classical mechanics, perturbations are found to initiate reproducible characteristic sequences of subsequent states of the system. In contrast with this unexceptional behavior, repetitive perturbation of an organism typically yields not only a distribution of alternative sequences, but transformations of this distribution as, for example, in the fixation of a habit under conditioning. In view of this situation it was readily appreciated that accurate prediction of the behavior of organic systems involved a new order of theoretical difficulty.

This "new order" of theoretical difficulty was certainly not restricted to the behavioral sciences alone. In thermodynamics and later theories of mechanics the problem of distributions of outcomes, and with it the accompanying requirement for the establishment of statistical criteria for the rejection of hypotheses, had to be faced in physics. The point of interest here is that problems of even higher order were encountered from the very inception of behavioral inquiry.

Thus, any expectation that complete descriptions (i.e., adequate factorization of essential measurable properties) for behavioral systems could be accomplished in terms of the familiar primitives adequate for inorganic systems had to be abandoned as hopelessly naive. Organisms clearly required a more complicated objectification, and the general recourse adopted in behavioral inquiry was to attribute to organic systems various collections of additional properties, which came to be associated ultimately with the general notion of adaptive control processes.

* This is not to deny that eminently respectable accomplishments in physiology, physiological psychology, and biophysics have been attained under direct extension of this strategy of inquiry. The point is simply that these attainments have been limited to investigations restricted to consideration of elementary subsystems of the total organizations or organisms that comprise the ultimate interest of inquiry in these fields.

This imputation of internal control processes under a new objectification had two notable results. First, there appeared in behavioral theories disconcerting numbers of new primitive constructs: reflex, expectation, attention, motivation, appetite, aversion, drive, instinct, habit, consciousness, id, ego, superego, norm, needs, utility, subjective probability, expected value—the full list would finally evoke incredulity. With the introduction of these new primitives the notorious problems associated with "intervening variables" and "hypothetical constructs"—in short, the whole question of unobservables—arose to plague behavioral inquiry and to generate, finally, the well-known reaction of radical positivism.

Without minimizing the importance of considerations regarding criteria of meaningfulness, interpretability, applicability, and practicability that ensued, which remain at the center of controversy concerning admissible constructs and measurable properties, it is the purpose of this paper to emphasize a second outcome. In the attempt to accommodate systems typical of the biosphere, classical objective theory has been utilized in a manner that is indicative of a trend toward modification of its theoretical perspective. A surface indication of this trend is the curiously unnoticed practice of referring to a supposed "object system" in certain areas of behavioral investigation as the subject. Behind this apparently innocuous terminology lies an implicit attribution of crucial degrees of freedom to organic systems. When the conceptual commitments* involved in this viewpoint are made explicit, it is clear that certain organisms, at least, are being objectified in terms of (a) hierarchical systems involving multiple levels of integrally related control processes that generate (b) characteristic patterns of response to stimuli via stochastic processes (i.e., selection or decision processes) that are motivated by (c) problematic situations involving maintenance or modification or institution of norms at all levels, resulting in (d) behavioral "programs" that may range, in sophistication of homeostatic response, from selectivity through ultrastability, conditioning, and learning and ultimately to cognition.

With regard to the taxonomy of adaptive systems proposed in this study, what is the significance of this trend in objective theory toward the conceptualization of organisms as subjects? First, it may be noted that this objectification is literally entailed by adaptive systems in general having been constituted as capable of reaction, renormalization, and reorganization—literally, three increasingly complex levels of homeostatic response. Next, an observation almost impossible to miss: That this objectification is patently based on a veiled analogy in which characteristics of human cognitive systems as subjects (available by introspection on the part of the theorizer) are attributed to organisms as objective properties. Finally, from the morass of problems generated by the attempt to employ this objectification in behavioral inquiry, it may be concluded that the trend toward modification of the objective-theoretic approach needs to be developed into a fully developed reorientation of theoretical perspective. The strategy of inquiry—a metascientific concern from the objectivist viewpoint—insofar as it controls the fundamental process of

* Note that the creative role of the theorizer in conceptualizing and selecting this new objectification remains covert. This is characteristic of the objective-theoretic approach.

objectification and selection among objectifications requires explicit formulation within an overtly recognized methodological structure.

Such a departure from the traditional objectivist conception of methodology—i.e., the injection of strategies, norms, decision operators, and decision principles at the level of formal theory—would constitute a reconstruction* of the basic theoretical enterprise in terms of the addition of a prescriptive or normative activity as a complement to the predictive aspect of inquiry featured in the objective-theoretic perspective. Thus the most significant result that can be drawn from the proposed taxonomy is the realization that, by virtue of its treatment of cognitive selective systems typical of the noosphere, a normative perspective for inquiry in general can be envisioned.

We begin with the consideration that the hierarchy of adaptive systems, with its incorporation of conceptual or symbolic systems, provides a category with respect to which we have peculiarly privileged access. For the analysis of these systems as products of the cognitive process, introspective data are available to the theorist. Although the formulation of a theory of cognition is still a decidedly open problem, we are able to appreciate—via the self-awareness of introspection—certain implications of the operations we perform in the reasoning process. Whatever we ultimately come to in the way of cognitive theory, it is surely incontrovertible that one particular feature will have to be acceded to: That cognition as an adaptive control process constitutes (a) a decision process operating to resolve (b) problematic situations (c) via the institution of selected policies as norms controlling (d) objectification and selection among objectifications capable of determining (e) an unambiguous line of behavior in the context of (f) terminal objectives (or values) under (g) the constraints of finite resources, subsystem stresses, and modification of idiosystem norms by an appropriate supersystem.

This is to say, in short, that cognition as an adaptive control process is identifiable as the general paradigm of the gradually emerging concept of heuristic programming.

The significance of this realization lies in its implication concerning the status of object constructs and cognitive models or theories, i.e., the conceptual entities that emerge from the heuristic activity of the objectification process. Such conceptual entities—instituted on a trial basis and objectified under the strategies, values, and norms of a cognitive agent—comprise, with that agent, a subject-object dual having the character of an emergent adaptive system. The total collection of such systems is precisely what has been designated the "domain of the noosphere."

With regard to the conceptions of adaptive systems throughout the taxonomic hierarchy, it is now imperative to note that all these constructs appear as elements of emergent conceptual systems in the noosphere. Even the basic conception of the related domains of the geosphere, biosphere, and noosphere

*It seems clear that there is no general tendency among behavioral investigators toward any such reorientation. The typical reaction to the injection of norms, values, and decision processes as properties of adaptive systems is that of the traditional objectivist: norms, values, and decision strategies are taken to be simply additional factual properties of certain classes of objects. Without attention to the consideration that these properties are being imputed under control of inquiry itself by strategies, norms, and values, the so-called "value sciences" are construed as being confronted only by additional problems of measurement. For a critique of this view see Smith.[26]

is itself an element of the noosphere. As indicated in Figs. 12a and 12b if the content of the noosphere is detailed, a situation arises in which one element of an initial gestalt consists of a replica* of that gestalt. In other words, the geosphere, the biosphere, and the noosphere are themselves conceptualized within the noosphere.

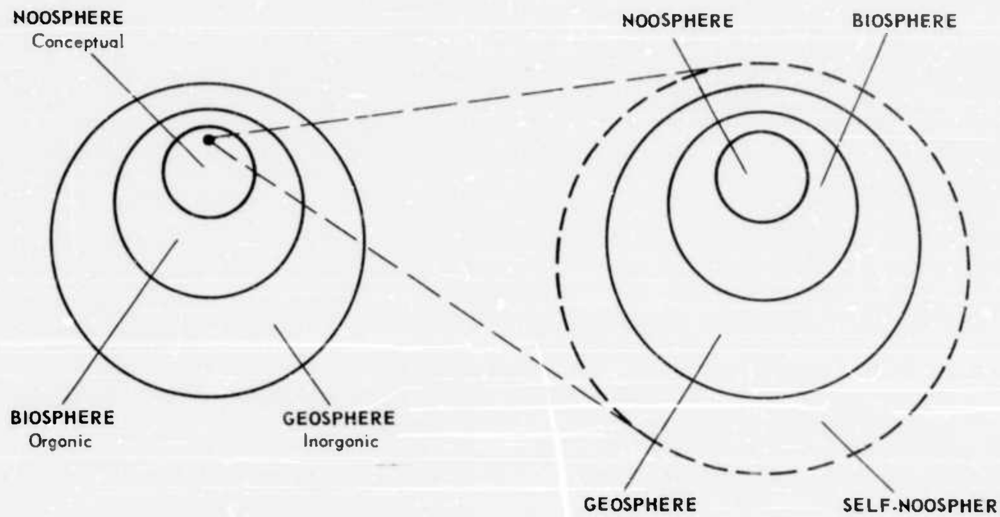


Fig. 12a—Domains of Systems

Fig. 12b—Concept of Domains of Systems
Detail of Fig. 12a.

It is clear, then, that the cognitive process affords a basis for placing any construct whatever in the context of an adaptive system, e.g., the subject-object dual composed of a cognizer and his problem of inquiry (or theory) as an object. The basic import of a normative-theoretic approach to inquiry is concerned with the possibility of systematizing the heuristic process of trial and error fundamental to objectification and selection. By formalizing the role of the theorizer as subject with regard to the adoption of metatheoretical controls for the selection among object theories, degrees of symbolic freedom may be generated in a hypermodel by means of which whole classes of objectifications become testable, converging onto a common theory as empirical data accumulate.

At this point the normative approach as a methodological option must be sharply distinguished from the imputation of normative character as an ontological option. The fact that any object construct whatever may be considered from the normative perspective of a cognitive decision system must not be

*Although this may be disconcerting at first, no actual difficulty is generated by this result. The situation is merely analogous to one in which we might propose that a certain general property holds among the elements of a given class of statements—our proposal being a statement belonging to that class. We should be gratified rather than dismayed to find that, indeed, our proposal does possess that property.

construed as suggesting the propriety of anthropomorphizing objects indiscriminately as self-systems (decision systems). To suppose that a thermostat or even an amoeba, for example, literally constitutes a deliberative decision system would be quite as objectionable under normative theory as under the objective approach. The point is that, as Bellman[9] has demonstrated, normative theory couched in the format of the mathematics of optimization can be utilized for the explanation of the behavior of even the most elementary mechanistic systems, with results that are precisely equivalent to those attained

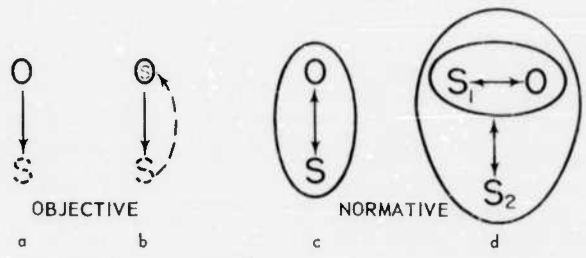


Fig. 13—Range of Theoretical Perspectives

under a deterministic approach. It is not a requirement of the normative approach to view such simplistic systems as making decisions that optimize their own norms; rather the optimization format represents merely a commitment of the theorizer to a general strategy by means of which a class of objectifications may be collectively considered. Subsequent empirical data will have the inevitable result of reducing the symbolic freedom introduced into the problem.

With this development, the range of theoretical approaches extant in behavioral inquiry may be summarized by the diagrams in Fig. 13a,b,c,d. The earliest version, a, following the technique of classical mechanics, assumes the existence of a deterministic object system independent of the observer as a subject. Under reobjectification necessitated by the evidence of incomplete factorization, b, the theorizer covertly attributes to the "object" additional properties suggested by his conception of a subject or self-system. With the realization that all object systems may be considered in the context of a subject-object dual, c, the prescriptive or normative approach is engendered; and with the objectification of a conformal hierarchy of adaptive systems, d, normative behavior at a given systemic level may be attributed to the object itself in a subject-object dual.

CONCLUSION

The new insight this study claims to disclose, then, does not ultimately concern merely the rudimentary taxonomy proposed for the domain of adaptive systems. A unitary hierarchy constituting the cosmographic domain of systems

is presumably only what anyone might presently attempt to construct as a representation of a generally acceptable premise concerning connectibility within the system of natural selection. There has long been a prevailing intimation of a unitary process of development; it had been advanced even earlier than Aristotle's explicit notion of a "great chain of Being" and it recurs in almost every systematic philosophy—most notably perhaps in Hegel's dialectic and most recently in Whitehead's conception of process and reality. There can be at present little question as to the general admissibility of this premise. The problem now, as always, is to render this vague intimation operationally meaningful, to vindicate the notion by attaining a rationale of systemic development that possesses predictive and prescriptive significance. That is, we must be able to show, in detail, how the patterns of development and behavior for the specific adaptive systems discriminated by contemporary inquiry are conformal with a unitary format of organization and transformation. It is our conception that the rudimentary taxonomy proposed here can contribute toward such an achievement.

The new consideration this study puts forward, in addition to the connectibility and conformality of adaptive systems in general, is the option of a normative-theoretic approach—a methodological commitment to the effect that the following procedures collectively comprise a superior strategy for inquiry with regard to the domain of adaptive systems:

(a) Decision-oriented analysis featuring the inclusion of a decision maker in a subject-object dual for the formulation of a hypermodel.

(b) Formal or theoretic attribution of organic character to all selective systems in the context of optimal programming.

(c) Reconstruction of epistemological—if not ontological—commitments to provide for increased complexity of theory addressed to even the most rudimentary systems.

(d) Utilization of sophisticated adaptive systems, i.e., cognitive systems, as paradigms for the identification of primitive concepts.

This normative approach would be complementary* to the objective reductionism that has been responsible for extremely fruitful scientific accomplishments but that now appears obstructive to major advance in the behavioral sciences. To do justice, in our primitive notions and in our theoretical format, to the complexity of adaptive systems seems to be the appropriate order of business.

It is our principal contention that a fruitful means of accommodating the complexity of adaptive systems is to be found in the additional degrees of (symbolic) freedom introduced by a hypermodel based on a formalization of the objectification-selection process in terms of (a) a subject-object dual and (b) a programming format incorporating the strategy of the inquirer. In addition to the efficiency of this theoretical approach (it deals, after all, with classes of objectifications rather than singular object-models), the complexity

*In the secondary sense in which "objective theory" is used merely for the connotation that a result of rational inquiry must be open to public scrutiny, the normative-theoretic approach itself may be said to be "objective." In a significant extension of this notion, however, the objectivity of a normative theory refers specifically to the requirement that (a) the theory be open to confrontation by input data that, on theory, are extraneous and (b) that the theory be stable and durable under such confrontation.

of any object-system is respected inasmuch as that system is allowed to "assert itself" through an experimental history that is relatively unconstrained by conceptual prejudgment of its ranges and degrees of freedom.

Finally, two subsidiary implications may be derived from this study: (1) the peculiar specialization of management science places it in the line of potential leadership with regard to new avenues of behavioral research and (2) the entire spectrum of disciplines comprising the behavioral sciences may profit immeasurably from new interconnections among specialties that are found to be associated—under a refined taxonomy—with adaptive systems at the same level of complexity. This is to say that when we are able to distinguish specific orders of complexity within the world of "black boxes," we shall be able to cooperate more effectively in the common task of their investigation.

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